ANALYSIS OF WORKLOAD PLANNING AND ALLOCATION
OF RESOURCES TO SUPPORT FIELD ADMINISTRATION
AND INSPECTION OF NAVAL FACILITIES ENGINEERING
COMMAND CONSTRUCTION CONTRACTS

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THESIS

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CONSTRUCTION CONTRACTS

by

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I. INTRODUCTION

This thesis examines the variables influencing the construction workload planning for the Engineering Field Divisions (EFD) of the Naval Facilities Engineering Command (NAVFAC) and investigates the means of forecasting the resources required for the administration and execution of their construction program. The relationship between the workload of the contract administration organization and the contracts to be administered is the basic problem addressed. The relationships used in the current system are examined and the desirability of a more appropriate resource allocation method is discussed. The identification and examination of variable factors affecting the existing resource allocation system is undertaken to show the relevance of these factors to the allocation problem.

The data used in this thesis was obtained primarily by researching reports and documents listed in the bibliography and by conducting numerous interviews with personnel having past and/or present involvement with construction workload planning and resource allocation. Those key personnel contacted who were of significant help in supplying relevant information, are listed in Appendix A.

This introduction provides the reader with a brief resume of the developmental stages of NAVFAC which has led to the current crucial need to balance requirements and resources.

It is within the Navy environment described below that the EFDs must manage the administration and implementation of the NAVFAC construction program.

The U. S. Navy traces its origin back to 1776 when the Continental Congress established the Continental Navy. Twenty-two years later when the Office of the Secretary of the Navy was established, the U. S. Navy fleet consisted of three frigates. The War of 1812 emphasized the need for a more efficient organization of the Navy Department so in 1815 a Board of Navy Commissioners was established to advise the Secretary of the Navy on technical and naval problems. This Board functioned until 1842 when it was replaced by the Bureau system.

The first Bureau established in the Navy Systems Commands was the Bureau of Navy Yards and Docks which became the Naval Facilities Engineering Command as a result of a reorganization of the Navy Department in 1966.

The responsibilities of the Bureau of Navy Yards and Docks were set forth in a Navy Department Regulation dated 26 November 1842 as follows:

> "The Navy Yard proper, the docks and wharves thereof; all buildings therein or appertaining thereto, including the magazine and hospital buildings; all machinery attached to the yard or ordinarily used in its operation; all vessels in ordinary; all boats, water tanks, hoys, etc., used for the purpose of the yard, all carts or other vehicles; all horses, oxen, used in the yard, and all other labour therein, and belonging to the objects of this Bureau; the police of the yard; all persons belonging to the yard or ordinary; all contracts and all accounts, returns, etc., embracing these objects or such as shall be from time to time assigned to this Bureau." [Ref. 12]

The Civil Engineer Corps came into existence when Congress passed a law in 1867 that made the Bureau's civil engineer a staff officer. The importance of the Civil Engineer Corps is indicated in the 28 January 1911 Report of the House Naval Affairs Committee which stated that all the public works of the entire naval establishment was to be consolidated under the Bureau of Yards and Docks which would be controlled by the Corps of Engineers in the Navy. That same year, Congress enacted a law which legally placed all Navy public works under the Bureau of Yards and Docks (Navy was dropped from the Bureau title in 1862).

Thus the enormous growth of the naval shore establishment from that of supporting a fleet of three frigates in 1798 to the support of the global naval complex of today has been the work of the Civil Engineer Corps through the NAVFAC organization.

The pace of the NAVFAC construction program has hit peaks during periods of conflict. The World War I construction program of $347 million was dwarfed by the $9 billion worth of facilities constructed during World War II. During the World War II period, ten thousand Civil Engineer Corps Reserve Officers filled the role of construction supervisors. The birth of the Seabees in 1942 added more than 250,000 military construction workers to the construction program of building overseas bases. During the Vietnam conflict a maximum construction work-in-place rate of $63 million a month was achieved. However, this recent period of relatively large resource allocations has apparently ended.

We are now in another era. The Civil Engineer Corps has an authorized strength of 1500 officers on active duty. U. S. forces have withdrawn from Vietnam, direct defense spending as a per cent of the Federal budget has been reduced, the military force level has been curtailed and some military installations have been disestablished. As resources become more scarce, it becomes increasingly more vital to have a resource allocation system whereby variable factors influencing logistic requirements can be evaluated and quantified, thus providing a more appropriate basis for achieving a balance between requirements and economy.

The mission requirements of NAVFAC includes providing support to the Operating Forces of the Navy, the Marine Corps, other components of the Naval Material Command, and other offices and organizations in regard to shore facilities and related engineering material and equipment [Ref. 12].

The first command objective listed by NAVFAC in their FY 1974 Command Management Plan is to ensure the availability of shore facilities and fixed ocean facilities necessary to support the Navy, at the best balance between requirement and economy [Ref. 12]. This objective presupposes that optimal relationships exists between logistic requirements and resources. These points of optimality, though never precisely definable or obtainable, are approached by considering trade-offs between benefits and costs in the utilization of scarce resources. This necesssitates the use of experienced judgment coupled with an analytical process to

determine what expenditure of resources is justified to minimize the future penalty caused by failure to meet mission goals.

The NAVFAC construction program is implemented through six engineering field divisions which also must balance construction workload requirements with the economy of scarce resources. The analysis of construction workload forecasting for the Engineering Field Division of the Naval Facilities Engineering Command and the establishment of relevant relationships between workload requirements and resources is the primary concern of this thesis. Also included as an aid in understanding the resource allocation problem is a background section describing organizational relationships and the NAVFAC management concept. The nature of the resource allocation problem is described in Section three. This is followed by an analysis of the current resource allocation system, and the identification and analysis of variables influencing the construction administration workload. Section VI discusses a possible classification system which could facilitate the identification of construction variables. The final section states the conclusions drawn from this thesis and makes some recommendations that may be helpful in improving the EFD resource allocation system.

II. BACKGROUND

A. ORGANIZATIONAL RELATIONSHIPS

1. Charter, Authority and Responsibility of NAVFAC

Within the Department of the Navy, the Chief of Naval Operations is the military construction sponsor and the overall Program Coordinator. Although the responsibility for the execution of the military construction program has been delegated to the Chief of Naval Material, it has been redelegated to the Commander, NAVFAC. This delegation of responsibility to NAVFAC includes all financial control and jurisdiction of the approved military construction allocation issued by the Comptroller of the Navy as well as the responsibility for all limitations thereon [Ref. 16]. NAVFAC also is responsible for ensuring that all allocations under the military construction (MCON) program are administered and controlled in accordance with laws and regulations relating to the administration of appropriations, including implementing regulations prescribed by the Comptroller of the Navy (NAVCOMPT).

The construction program implemented by the NAVFAC organization includes: development of construction program objectives and annual programs; the processing of documentation and liaison work from the customer activity to Congressional levels; budgeting and allocation of design and construction funds; the development, processing, and budgeting for emergency construction requirements; technical

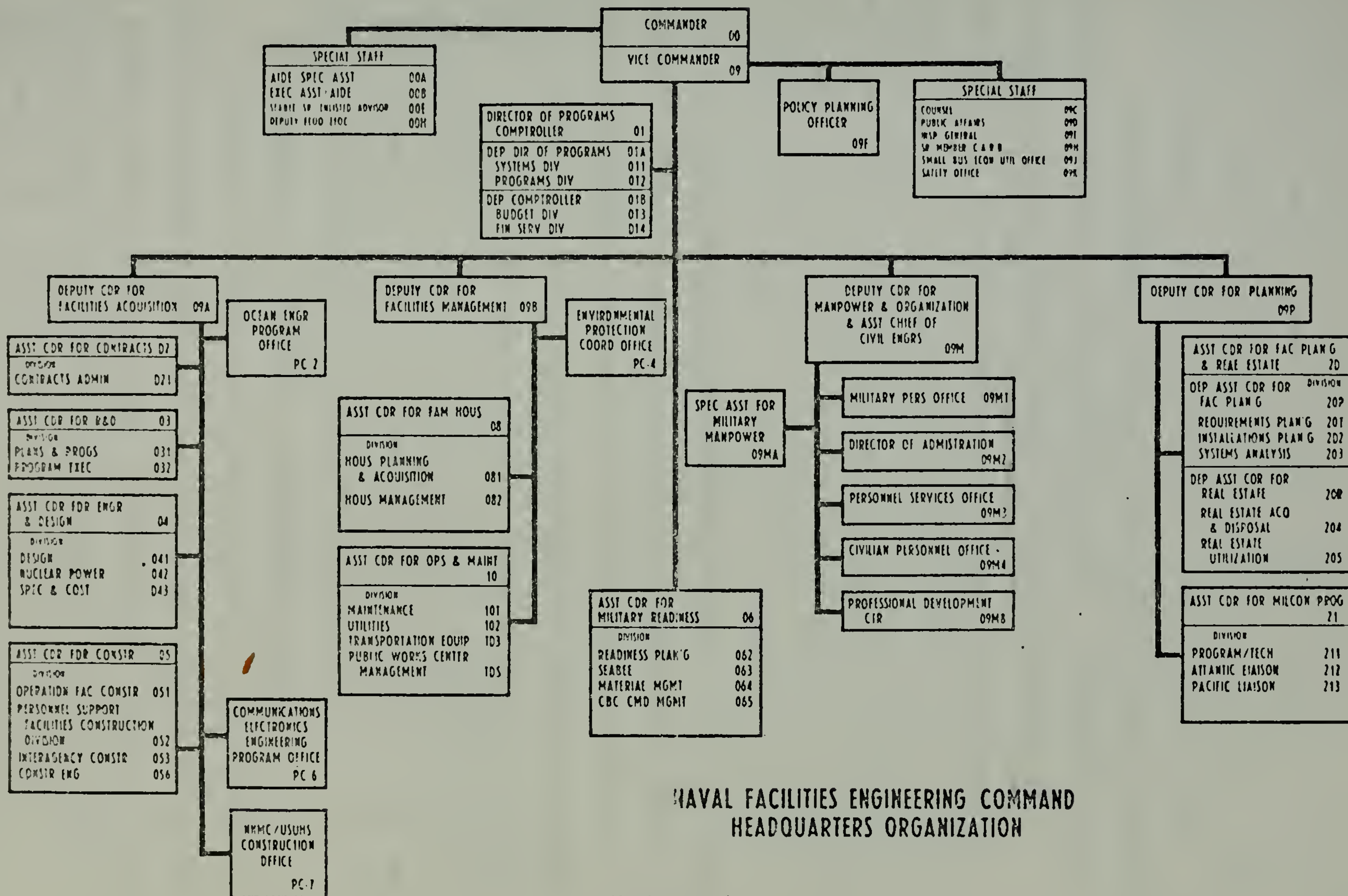
direction of facilities engineering and design; and administration of quality control and resource management during actual execution of construction projects.

The NAVFAC mission operations are directed from a Headquarters office and executed through primary field activities. The Commanding Officers of these decentralized activities have broad decision authority within command policy, standard procedures, and resource assignments. The primary field activities of NAVFAC are the Engineering Field Divisions, Public Works Centers and Construction Battalion Centers. Of these activities, the Engineering Field Divisions are responsible for implementing the military construction program. Figure 1 depicts the NAVFAC headquarters organizational structure.

2. Authority and Responsibility of EFDs

These activities are similar to NAVFAC Headquarters in both organizational structure and in operational programs. There are six EFDs assigned to broad geographical areas. Four EFDs cover these United States while one each covers the Atlantic and Pacific area.

The authority for Navy procurement vested by statute in the Secretary of the Navy and delegated to the Commander, NAVFAC for construction has been redelegated to the Commanding Officers of the EFDs to the maximum extent feasible. Delegation to the EFD Commanding Officers includes authority to prepare, award and execute for the Commander, NAVFAC all contracts applicable to military construction except



NAVAL FACILITIES ENGINEERING COMMAND
HEADQUARTERS ORGANIZATION

FIGURE 1

negotiated architect-engineer contracts greater than $600,000 and certain change orders. Change orders excepted are those which are either greater than $600,000, out-of-scope, exceed funds available, or exceed the basic contract price [Ref. 16].

The Commanding Officer of each EFD is also designated Officer in Charge of Construction (OICC). Actual construction and contract administration including inspection is supervised by Resident Officers in Charge of Construction (ROICC) who are stationed at or near the job site. Contract award and change order authority is usually retained at the OICC level, however, limited OICC authority may be delegated to ROICCs at the discretion of the EFD Commanding Officer.

Figure 2 depicts the general organizational layout of an EFD. The two areas most directly involved in the resource allocation process are the construction division which makes the allocation and the ROICC field office which is the recipient of the allocation. The management analysis division in the comptroller department is also important in the allocation system since it is the load point for data into the EFD management information system (MIS).

3. Synopsis of Military Construction Cycle

Military construction should never be an end in itself but rather a means to an end. The central objective of NAVFAC is to serve the Navy responsively. Figure 3 is a schematic diagram showing the relationship of the various participants in the process of converting Naval support deficiencies from requirements to completed work-in-place

STANDARD ENGINEERING FIELD DIVISION ORGANIZATION CHART

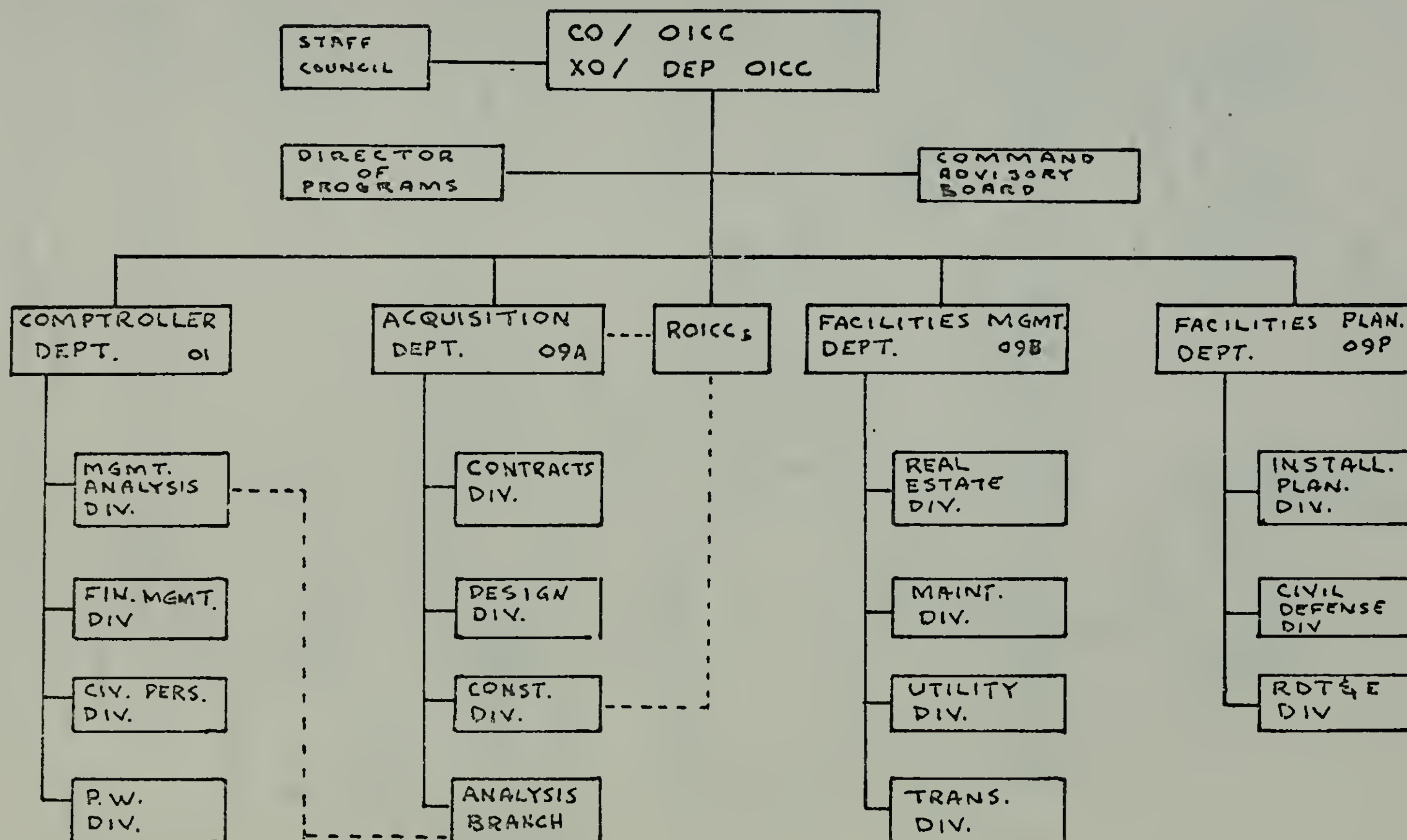


FIGURE 2

NAVY MILITARY CONSTRUCTION CYCLE

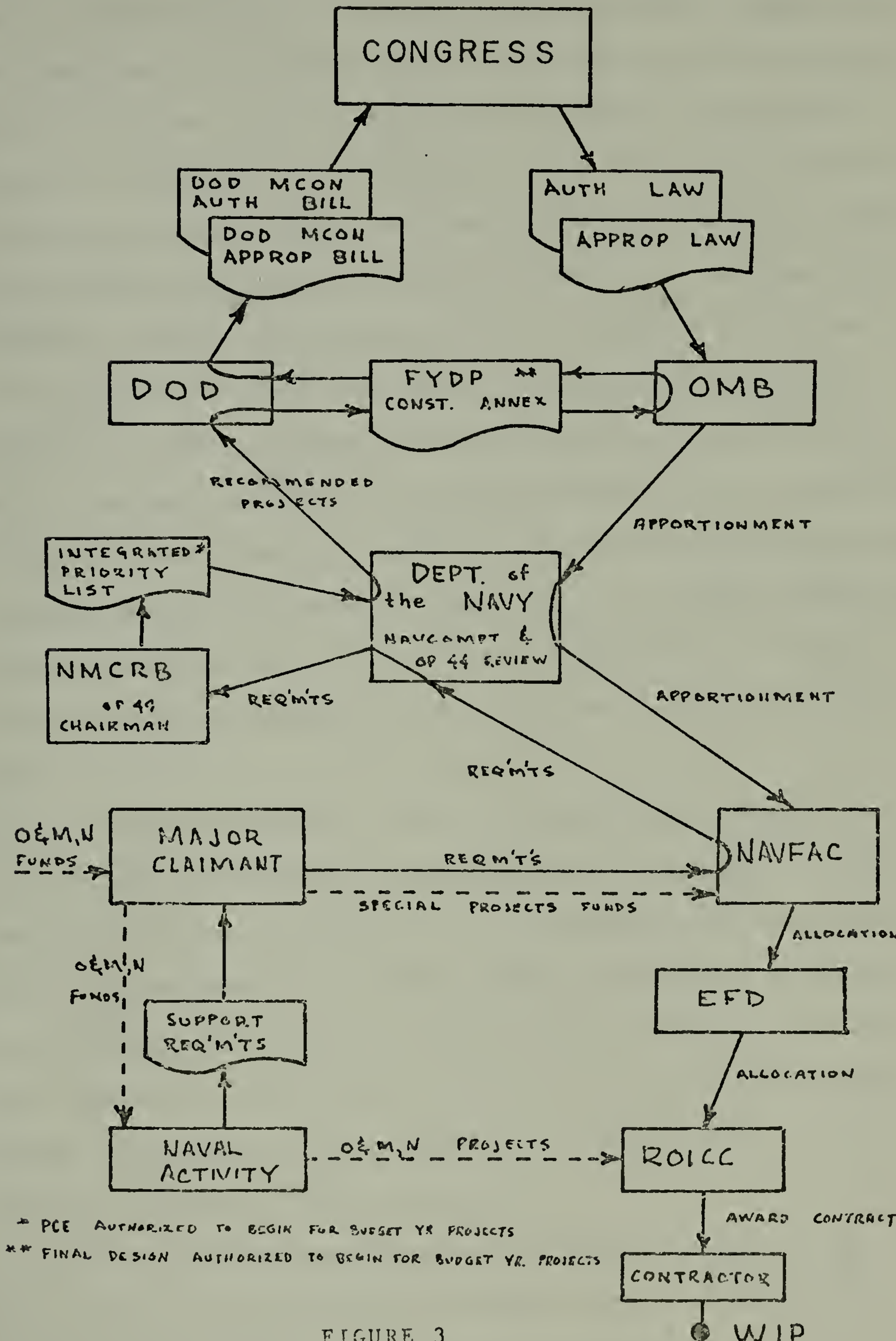


FIGURE 3

(WIP). From an EFD viewpoint, significant decision points are the Navy Military Construction Review Board (NMCRB) and the Department of Defense (DOD) where the construction annex to the five year defense plan is formulated. The NMCRB decision results in an integrated construction priority list. All projects recommended for funding during the budget year by the NMCRB are automatically approved for a program cost estimate (PCE) to be prepared by the cognizant EFD. The objectives of the PCE are, first, to determine the most effective means to satisfy the requirements defined by the major claimant; second, to develop engineered cost estimates; and third, to serve as a basis for the subsequent preparation of plans and specifications [Ref. 16]. The NMCRB integrated priority list could be loaded into the EFD/MIS data base for use as an approximation of projected WIP for the budget year.

The DOD decision point is significant because it is at this point that the cognizant EFD is authorized to begin design on projects included in the Construction Annex to the Five Year Defense Plan (FYDP). The Construction Annex list of projects could also be loaded into the EFD/MIS so that the tracking of anticipated military construction projects can be kept current and available for EFD personnel as an aid in projecting future workload.

The next major decision point takes place in the Congress and results in two separate laws, the Department of Defense Military Construction Authorization Act and the

Military Construction Appropriation Act. The Navy portion of the Authorization Law includes the authority to construct or acquire new facilities, authority to proceed with emergency construction without further specific Congressional approval, and amendments to previous laws for facilities which could not be built within the original authorization. The appropriation is always for a lesser amount of funds than the Authorization Law [Ref. 16].

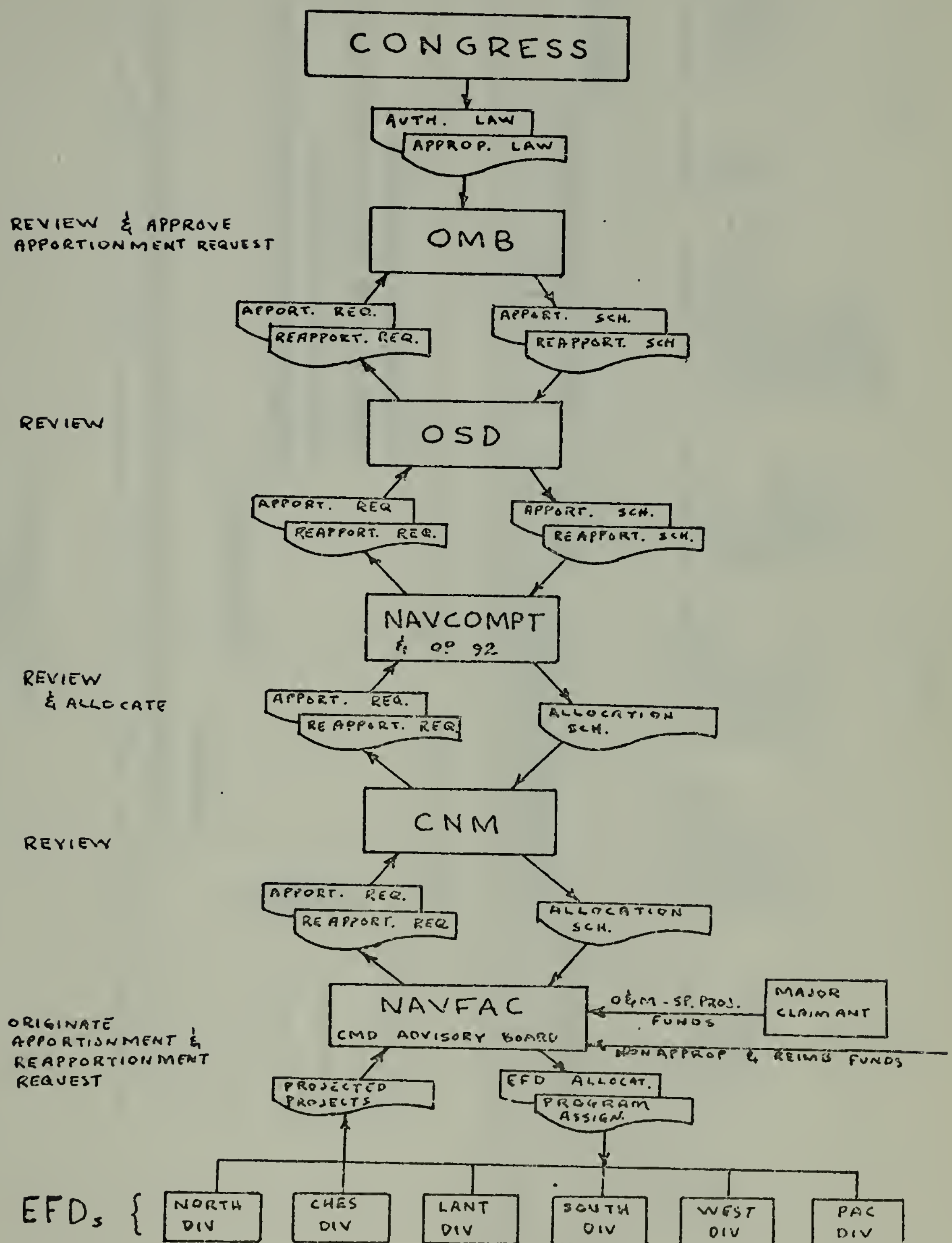
Congress approves the expenditure of funds but final authority for release of funds for obligation rests with the President until delegated to others. Currently the Office of Management and Budget (OMB) performs this function by means of an apportionment process which allocates money for the military construction program. All Navy major construction project funds are channeled to NAVFAC and amounts to approximately $630 million annually. Additionally minor construction project funds (i.e., projects under $50,000 and usually operations and maintenance funds) may come to NAVFAC via the major claimant or individual naval activities. Operations and maintenance, Navy (O&M,N) funded projects amount to approximately $100 million annually.

Execution of the military construction program within NAVFAC is assigned to the Assistant Commander for Construction, who is also designated the Construction Program Manager. Within the EFD the Director, Construction Division makes the final allocation of resources to the ROICC units.

Figure 4 depicts the Navy military construction funds flow. This process begins when NAVFAC receives an advance copy of the Authorization and Appropriation Laws and prepares an apportionment and reapportionment request. The apportionment request applies to new projects and requests funds equal to 95% of the current working estimate (CWE). The reapportionment request is for completion of projects already started and requests funds equal to 100% of the CWE. It should be noted that the CWE as carried in the Construction Management System (CMS) data bank will change each time the system is updated by progress. At any point in time the CWE should be the best estimate available and should include allowances for all unknown contingencies. The apportionment requests based on CWE's are transmitted through the chain of command to OMB for approval and come back down to NAVCOMPT where an allocation schedule is prepared. This allocation schedule is then transmitted to NAVFAC where fund allocations and program assignments are made to the EFDs.

The relative timing related to military execution tasks is shown in Figure 5. This diagram also shows the structure of expenses related to military construction execution. The two basic funds shown are planning, and supervision, inspection and overhead (SIOH) funds. The planning funds are an annual appropriation for such tasks as preparing the PCE and for design work. The SIOH funds are used for executing the approved military construction program and are borne by the construction appropriations themselves.

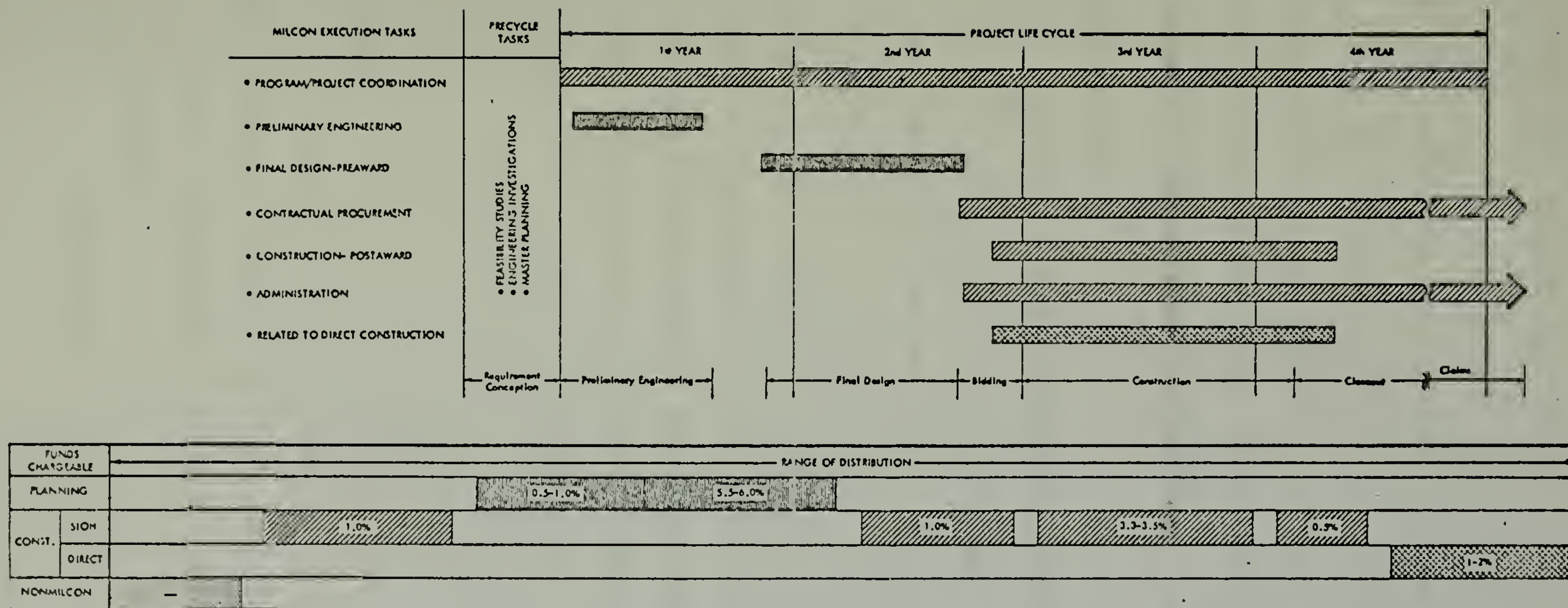
MILITARY CONSTRUCTION FUNDS FLOW



EFD ALLOCATIONS ARE IN TOTAL FOR EACH DIVISION BASED ON SUM OF THEIR PROGRAM ASSIGNMENTS.

FIGURE 4

STRUCTURE OF EXPENSES (CHARGES)
RELATED TO
MILITARY CONSTRUCTION EXECUTION



PRE-CYCLE TASKS
Feasibility Studies
Engineering Investigations
Master Planning

PROGRAM/PROJECT COORDINATION
Customer Liaison
Execution Planning
Allocation of Funds
General Coordination of Project throughout life cycle

PRELIMINARY ENGINEERING
Program Cost Estimate (Preliminary Engineering Report)
Land Planning Studies
Subsurface Explorations
Topographic Surveys
Reproduction
Supervision/Review of Above
Witness Data
Related Overhead

FINAL DESIGN PRE-AWARD
Plans and Specifications (including Redesign Due to Breakages)
Subsurface Explorations
Topographic Surveys
Prebid Estimate
Materials Testing
Value Engineering
Supervision/Review of Above
Reproduction
Related Overhead

CONTRACTUAL PROCUREMENT
Long Lead Material Acquisitions
Bid Documents
Prebid Conference
Bid Taking
Contract Award
Change Order Issue
Process Payment Vouchers
Investigations Related to:
Proposed Contractor Responsibility
Time Extensions
Claims
Final Closeout/Release

CONSTRUCTION POST-AWARD
Technical Direction/Supervision Includes:
Preconstruction Conference
Definition/Negotiation of Change Orders
Letters of Direction
Review/Approval of Contractor Schedules, Estimates, Shop Drawings, Progress Payment Requests
Property Administration
Material Expediting
Inspection
Materials Testing
Labor Relations Program
Claims Negotiation
Contract Completion Report
Land Acquisition Processing
Initial Outfitting
Safety

ADMINISTRATION
Personnel
Fiscal
Training
ADP Support
Legal
Executive Office

RELATED TO DIRECT CONSTRUCTION
Design for Changes
As Built Drawings
Value Engineering
Post Completion Evaluation (e.g., Pavement Evaluation, for Benefit of Future Design and/or Correction of Construction Deficiencies)

[Ref. 16]

FIGURE 5

The EFDs and ROICCs are at the end of the military construction cycle where Congressionally approved projects and dollars are converted into actual construction work-in-place. It is therefore at the EFD level where the need for matching resources with the ROICC's workload is considered to be most critical and where the development of a more appropriate allocation model is desired.

B. MANAGEMENT CONCEPT

The Naval Facilities Engineering Command is responsible for many tasks and functions in performing its mission of support to the operating forces of the Navy and the Marine Corps. For simplicity of operation and to reduce organization interfaces in the administration of its mission, NAVFAC has established a functional form of organization using management by objectives, whereby each end-product responsibility has been defined as a program. There are nine functional programs each of which is managed by a Civil Engineer Corps officer, the Program Manager. The senior civilian assigned in each program is the designated Program Coordinator. The determination of goals, priorities, specific end products and resource allocations are effected through this program effort which converts Command mission into achievement.

The functional programs are designated by Roman numerals I through X as follows:

1. Program I Research
2. Program II Planning and Real Estate

3. Program III Engineering
4. Program IV Construction
5. Program V Military Construction Programming
6. Program VI Seabees
7. Program VII (Vacant)
8. Program VIII Housing
9. Program IX Public Works
10. Program X Administration

The Construction Program management is based on the concept of work-in-place (WIP). Annually, each EFD, in a budget submission, prepares the estimates of expense involved in administering the military construction program along with a projection of its WIP for the next fiscal year. NAVFAC reviews these submissions and approves a projected WIP estimate for each EFD. They also establish WIP targets and schedule plans, by quarters, which cannot be exceeded without further approval of NAVFAC. From the total of these estimates, the total estimated income and expenses are determined from projected WIP targets. Each EFD is then authorized to incur SIOH costs within his approved target. Thus, the staffing allowed, plus other expenses required to administer the program, is limited by the predicted income from projected WIP [Ref. 16].

III. NATURE OF THE PROBLEM

Executive action must follow an operating strategy if basic organizational objectives are to be obtained through maximum utilization of resources. In the dynamic society of today the operating strategy must be flexible enough to encompass numerous variable influence factors or suffer the catastrophe of rapidly becoming obsolete by technological developments, environmental requirements, new construction methods, and labor and environmental policy changes. The evaluation of variable factors which influence the EFD's allocation of resources to support a dynamic construction workload indicates the need for an analytical process or improved method of relating construction workload with optimal resource allocation.

The Construction Control Manual issued by the Department of the Army, Sacramento District, Corps of Engineers states, "Quality and durability of the completed work is a direct reflection of the experience, pride and judgment exercised by a responsible engineer at the project level. Satisfactory construction is obtained through emphasis on visual inspection and use of engineering judgment" [Ref. 1]. Quality and durability are recognized as sub-goals of all construction projects but the amount of quality and durability required for satisfactory construction is a variable. The Corps of Engineers' statement, which is in agreement with concepts

expressed by NAVFAC Construction Division personnel uses key words like experience, pride, and judgment. These laudable concepts are also variables subject to many environmental and motivational factors. Management judgment plays an extremely important role in allocation decisions but with many non-quantifiable variables influencing workload requirements, consistency among decision makers using experience and judgment alone is almost impossible.

Current procedures use WIP as the prime basis of determining staffing needs even though it is recognized that a universal factor applied to projected WIP will at best only translate into a rough approximation of local field office requirements. This results in projections of resource needs that do not accurately relate to the actual requirements at the many different field sites. Subjective judgment is, therefore required in order to smooth out these differences. Consider, for example, two ROICC offices with a WIP rate of $10 million per year. The first field office administers one large contract comprising low risk construction adjacent to the ROICC office in an area with a 14" mean average annual rainfall. The second field office administers many small contracts widely dispersed covering high-risk construction in an area with a 32" mean average annual rainfall. Both field offices are allocated resources from the same EFD. The WIP rate method of staffing would allocate the same number of inspectors to each field office even though it is obvious that the actual workoad at each field

office is completely different and influenced by many factors other than actual total dollar value of WIP. Each EFD construction division director contacted was aware of this problem. To compensate for the differences in workload, each uses a judgment factor tempered with experience to modify the initial allocation based on WIP rate alone.

The nature of the problem addressed is that of identifying the NAVFAC construction workload variables and analyzing their relevance and sensitivity to the resource allocation problem. This could then be used as a framework for a follow-on project such as developing a mathematical model. This would not make management decisions automatically but could assist management personnel as an aid in the planning, coordinating and achievement of equitable resource allocation. The difficulty lies in translating identifiable construction workload variables into a quantitative form such as man-years of effort.

IV. CURRENT PROCEDURES FOR ALLOCATION OF CONSTRUCTION RESOURCES

A. BASIC CONCEPTS

The NAVFAC program manager for the Construction Program (the Assistant Commander for Construction), is responsible for the management of construction resources. This program provides administrative, contractual, and technical services in the execution of the Navy Construction Program in efforts to achieve timely facilities combining high quality construction at minimum cost. The program managers responsibility for the management of all MCON, Military Construction, Naval Reserve (MCNR), and other assigned engineering and construction programs is command-wide. Through his headquarters and field organizations he oversees the administration of manpower, money, and other resources assigned for the execution of engineering services, construction, and quality control.

1. Supervision, Inspection and Overhead Costs

Funds required for administering projects of the MCON Program must be provided by the program appropriation. Each appropriation, therefore, includes funds specifically allocated to cover SIOH costs. In the past this percentage has varied with changes in the total construction workload. In recent years it has remained constant at 6 percent, since the actual workload has remained relatively steady. The cost of the program is larger primarily due to inflation

which has affected costs of administration as well. All types of projects are not charged the same flat rate. Six percent is applied against MCON, MCNR, Civil Works Projects, contracts financed by the Navy Industrial Fund, Research and Development Funds, Navy non-appropriated funds, and other procurements for the Navy and Marine Corps. Projects for the new construction of family housing and trailer parks, and improvement projects (excluding minor construction), however, are charged $3\frac{1}{2}$ percent. Civil works projects for which only contract administration is supplied are charged 3 percent. Each project is charged the appropriate flat rate regardless of the actual costs incurred.

The legality and size of the flat rate charge has been questioned frequently enough to cause Congress, within Section 704, Public Law 91-142, MCON Authorization Act, 1970, to encourage competition. The previous requirement that all construction had to be supervised by the Corps of Engineers or NAVFAC was eliminated. Congress then opened the door to competition by authorizing the execution of construction contracts under the jurisdiction and supervision of any agency approved by the Secretary of Defense. The Air Force has interpreted this to mean that the SIOH fee for each contract should be negotiated separately [Ref. 16, p. 7-14].

Contracts funded by O&M,N monies do not earn SIOH to cover the costs of administration. In this case, funds for support of this task are incorporated each year within the "mission management funds" alloted to NAVFAC by the

Naval Material Command. The required funds must be requested in NAVFAC's budget.

The SIOH earned and the allocation of O&M,N funds for execution of O&M,N contracts are the only sources of funds used to support the field offices. SIOH must be used to finance salaries and related costs of personnel, supplies, equipment, and materials that are directly associated with construction project management and program execution, plus a proportionate share of the salaries and related costs of personnel who provide general support (e.g., accounting and office services). It is NAVFAC policy to consider these funds to be earned and available for expenditure only for that percentage of construction that is completed (work-in-place)[Ref. 16, p. 7-5]. For example, when a $100,000 contract is 30 percent complete, or WIP is calculated to be $30,000, the SIOH earned equals $1,800.

In order to prevent the expenditure of unearned funds it is important that staffing and other related costs do not exceed the earned SIOH. Since WIP is the basis for earned revenue, it is essential that it be estimated as accurately as possible.

2. Tools For WIP Projection

An important tool used for estimating WIP on a month by month basis is a chart based on a set of curves commonly called "fair weather" or "S" curves. This chart, Appendix B, can be used to calculate both an estimated duration and a rate of completion per month based on the dollar value of

the contract. The source of the original curves, Appendix C, titled "Babcock Curves" is unknown. Sources within NAVFAC, the U. S. Army Corps of Engineers and the General Services Administration, who are currently using these curves or a version of them, were unable to identify or determine the origin of the curves or any of the background data used to derive them. These original curves were 13 in number and covered contracts with an estimated duration of 7 months to and including a duration of 19 months. In the early 1960s an attempt was made by NAVFAC to examine the accuracy of these curves, however, the studies were not completed, nor were firm conclusions drawn. In approximately 1965 it was decided that the thirteen curves were similar enough to derive a single curve to be used for contracts of any duration. From this curve a chart for durations from 0 to 60 months was formulated for ease of handling. As the name "fair weather curves" implies, these curves and charts provide the expected percentage of work put in place per month assuming no interruptions due to bad weather. Included with the fair weather curve is a chart relating total project cost to expected duration in months. By knowing the project cost, an estimated duration and then a rate of placement per month can be obtained as a percentage of total cost. This then provides projected WIP in dollars per month.

The EFD/MIS includes the CMS (a sub-system), which provides in one data bank, current and applicable information on the construction program. Upon full implementation, in

early FY-75, a computer program and its related report, "Work In Place (WIP) Construction Contract Status Report", will be provided on a regular basis. The EFDs will load all necessary data with the exception of the monthly projections, which will be calculated by the computer. The calculations will be done using the 60 month WIP projection chart which has been incorporated directly into the program. For example, an EFD will load data for a particular contract, including the CWE, the estimated start date, and the contract duration. From this information the computer estimates WIP commencing a minimum of 30 days beyond the start date provided. The duration is increased by two months to compensate for slippage due to material delays, problems on the job and so forth. The computer then calculates the estimated WIP for the projected contract duration. After the contract is underway and actual WIP is input, the estimates are updated on the basis of the remaining time and work. The present method of updating consists of distributing the difference, between the actual and projected, over each remaining month by the proportions of the "S" curve. By understanding the computer program, each project manager may still use his judgment by adjusting the input to the computer. An example of the calculation process is provided in Appendix D.

B. ESTIMATION OF WORK IN PLACE/REVENUE

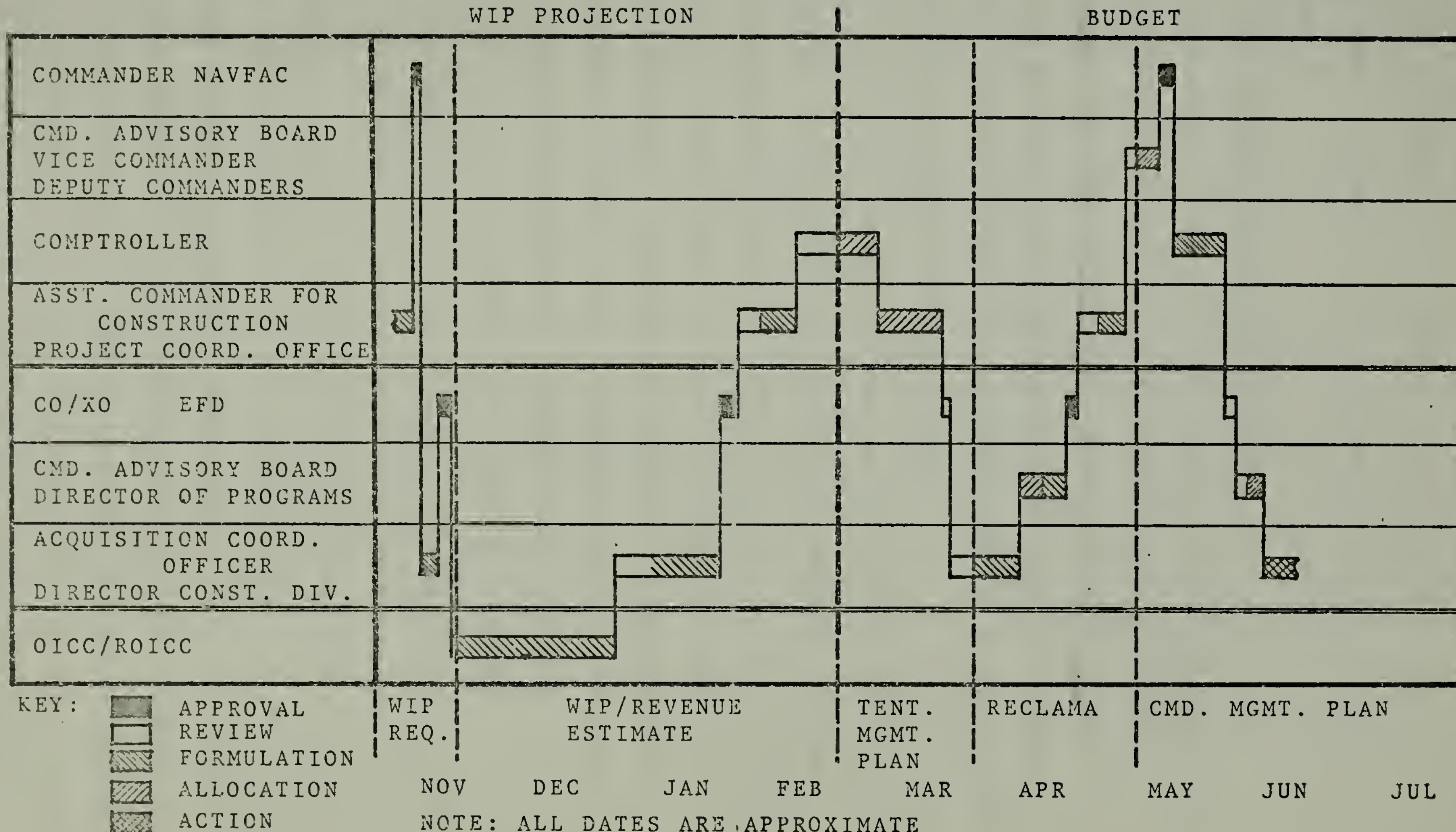
In November of each year, NAVFAC requests all EFDs to submit their estimated annual construction program workload

data for the next fiscal year. This data is used to estimate the SIOH to be earned from reimbursable contracts and to determine each EFD's projected workload. Each EFD then requests all ROICC offices to forward detailed information on current projects and all those anticipated to be awarded during the next fiscal year. This generates a chain of events, depicted by the chart in Figure 6, which culminates in the final determination of the staff required for each location.

1. <u>The Office of the ROICC</u>

The ROICC normally makes a rigorous review of the workload report that is prepared by his staff and forwarded to the EFD. Usually included in the report are: (1) project title (2) source of funds (3) time for completion (4) estimated dollar value if not yet awarded and (5) estimated contract award date. Included are both types of projects, reimbursable (SIOH to be received) and non-reimbursable (those for which SIOH is not received). The ROICC must check with the commands for which he provided support to obtain a funding schedule for contracts to be funded by O&M,N funds, non-appropriated funds (projects for which Congress doesn't appropriate funds, e.g., Navy Exchanges), and those funded through special projects. The EFD normally has prior information on special projects and those supported by non-appropriated funds. Often, however, the EFD has little or no information on O&M,N funded repair work until the money is forwarded for advertisement and award. The

RESOURCE ALLOCATION FLOW CHART



NOTE: ALL DATES ARE APPROXIMATE

FIGURE 6

ROICC also provides the EFD with schedules for work in progress that are based upon information supplied by the contractor.

2. The Engineering Field Division

The director of the construction division utilizes the ROICC report as an aid to estimating the WIP. The construction division staff will cross check the ROICC report and provide input regarding MCON starts, special projects, projects funded by non-appropriated funds and any other information they have received.

In order to determine the estimated WIP for a particular year it is standard practice to estimate WIP per month for each contract. WIP estimates for projects under construction can be taken from the progress schedules. Projects not under construction, that have been approved, or are expected to be, are a much more complex problem.

The first step is to estimate an award date. The selection of the award date is affected by a number of factors; expected date for apportionment of funds, the expected date for completion of plans and specifications, the legal requirements for advertising and bid opening, and estimated duration of the contract. The estimated date for award is based upon the best available information. Since the plans and specifications for MCON projects are usually completed prior to apportionment of funds, the date for apportionment is normally used to start the advertisement and award sequence. Standard practice is to add 45-60 days for advertisement,

bid opening, and NAVFAC approval (for projects over $100,000), to the estimated date for availability of funds. Particular dates may be modified based on expected delays or unusual occurrences, such as, readvertisement or negotiation of a bid received from a single source.

Once an award date has been selected it is necessary to determine an estimated duration to complete construction. If this can't be obtained from the architect and engineer firm doing the design work or the design division of the EFD, a rough estimate for construction time can be obtained from the "Fair Weather Curve" charts, as explained earlier. Currently this information is being input into the computer for calculation of the monthly WIP figures as described above. WIP is calculated for all current contracts and those with a high likelihood of approval as viewed by the construction division staff. The figures are listed on a spread sheet and forwarded to NAVFAC under the title "Workload Data - Military Construction Program FY 7_". At this point the Northern Engineering Field Division (NORTHDIV) applies a reduction factor of nine percent to all annual totals to adjust for expected project slippage or drop out. This empirically based factor was derived from historical data, i.e., the estimates have been nine percent high in previous years. Not all EFDs make such an adjustment.

Included in this report is an estimate of the number of man-hours required for construction administration. The estimate is made by each EFD utilizing an historically

derived factor relating estimated WIP to man-hours of construction administration effort. For example, for each million dollars worth of reimbursable construction, NORTHDIV estimated 1.87 men per year were required to administer the program. For O&M,N funded construction the "rule of thumb" used was 2.29 men per million dollars WIP. In order to determine annual man-hours, the number of men is multiplied by 1760 (the average number of hours worked per year taking into account annual and sick leave). Conversion into man-years of effort (based on 2080 working hours per year) is accomplished by simply dividing man-hours by 2080.

A second report, Program IV Man-year Requirement (Construction Only), is forwarded at the same time. It provides a listing of the man-years required to support the EFD and each ROICC office, separating out three areas, contract award and close-out procedures, construction administration, and program coordination.

3. <u>The Naval Facilities Engineering Command</u>

The reports are reviewed, updated and consolidated by the Program Coordination Office and then used to estimate total revenue. Only the total WIP for reimbursable projects is considered since all O&M,N funded and other non-reimbursable projects do not have SIOH applied.

The Program Coordination Office has more current information on the status of the various projects, therefore it becomes necessary to adjust the estimated WIP due to projects that have been deleted or added, award dates delayed,

or costs changed due to change of scope required by Congress or the customer. These revisions are made on the spread sheets and a copy is returned to each EFD for review, comment, and planning. The adjusted WIP estimates for reimbursable projects are then used to forecast total SIOH to be earned during the next fiscal year. This information is forwarded to the NAVFAC comptroller for budgeting purposes.

C. BUDGETING

The basic planning document of NAVFAC is the "Command Management Plan", NAVFAC P-441, which is issued in June of each year for the coming fiscal year. It is considered to be compatible and integrates with the Planning, Programming, and Budgeting System of the Department of the Navy and the Department of Defense. This plan provides the resource allocations for all NAVFAC programs in terms of dollars and man-years. The dollar figure is a firm target, but the man-years are ceiling limitations (maximum personnel that can be hired). Additionally the plan includes the WIP targets that were used as a basis for the projected SIOH earned.

1. The Naval Facilities Engineering Command

The NAVFAC controller after receiving the SIOH forecast allocates it among the several programs that have contract administration responsibilities. Program IV normally receives approximately 60 percent of these funds while Program X is allocated the bulk of the remainder to cover costs directly related to the MCON program (e.g., program management, accounting and budgeting). The Program Coordination

Office has the prime responsibility for allocation of Program IV resources among the EFDs. Using the target provided by the Comptroller, the Program Coordination Office allocates it to each EFD by major goals as a Tentative Command Management Plan. Dividing up the funds in order to properly support each EFDs workload is done with the aid of historical guidelines and personal judgment.

Calculations are made to determine the man-years of effort which historically (during the past year) have been required to support each million dollars of WIP. Additionally an average area man-year cost is determined by dividing all the previous year's costs for support of Program IV by the man-years of effort supported. Estimated man-years of effort are found by multiplying the projected WIP in millions of dollars by man-years/per million dollars. The estimated costs are determined by multiplying the estimated man-years by the average man-year cost. These estimates are guidelines to be used as a starting point. Adjustments are made to compensate for known inaccuracies in historical data and expected unusual requirements.

Program IV also receives appropriated funds from the Naval Material Command to support O&M,N funded projects. These funds are requested several years in advance as a portion of NAVFAC's O&M,N Program Objective. The quantity of funds required to support the O&M,N projects must therefore be estimated using historical data and expected trends. Although requests have been made to charge SIOH against

these projects, the requests have been denied on the basis that it is considered a NAVFAC mission to support them [Ref. 8]. This block of funds received each year is allocated to the EFDs on the basis of the estimated workload. These funds must cover all costs related to construction administration, contract administration, and program coordination. Additionally, for projects under $10,000, design costs are paid from these funds, but, for those greater than $10,000, design costs must be borne by the user command.

The NAVFAC controller consolidates the data from each program manager and compiles a Tentative Command Management Plan (also called Tentative Operation Plan) listing the target figure for major goals. The plan is forwarded to each EFD for comments in reclama. After receipt of comments, each program manager presents and defends his portion of the plan along with any justification for change to the Command Advisory Board (CAB). This Board, composed of the Vice Commander of NAVFAC as chairman, all deputy commanders and program managers, reviews, revises as necessary, and submits a recommended plan which then must be approved by the Commander of NAVFAC.

NAVFAC makes an official mid-year review to revise the WIP estimates expected revenues and the expenditures expected and incurred. Reallocation of funds and man-years often occurs among the EFDs, especially whenever they are very far from their targets.

2. Engineering Field Division

The tentative NAVFAC Command Management Plan is provided to each EFD program manager as a target figure within which he is to meet his objectives and goals. Each manager must determine if he can reach the goals set within the funds allocated; if he can not he must request and justify the requirement for additional funds to the CAB. This board, consisting of the Director of Programs as chairman and each department head as a member, reviews the Tentative Command Management Plan and the reclamas of each program manager. Utilizing this information the board allocates the funds to each program. The EFD is assumed to receive a pool of funds which may be allocated as their judgment dictates, regardless of how NAVFAC has allocated them within the NAVFAC Command Management Plan. Normally the amounts do not vary by much. The Acquisition Coordination Officer, when defending Program IV budgets, has a very strong claim to the funds and man-years allocated by NAVFAC, since these funds, through the WIP calculation, are considered related to an identifiable workload.

The revised Command Management Plan, as issued by NAVFAC is used to make the final adjustments to the EFD Execution Plan. Adjustments in the form of amendments may be made to both plans at anytime during the year.

D. STAFFING OF CIVILIAN PERSONNEL

Within each EFD the Director of the Construction Division is responsible for providing civilian staffing and support services to the ROICC Offices within his area of geographic responsibility. Each construction division director determines his support requirements subject to the limiting factors of personnel ceiling, and dollars. In other words, the major question is how many personnel can be supported. During periods of high workload the ceiling restriction will normally limit the number of authorized personnel, even though funds and work would be available for hiring additional personnel. In this case contracting for inspection services, from an architect-engineer firm, is often done, even though it is costly in the short run. For periods of lower workload, the situation is reversed and funds are restrictive. The Director of the Construction Division allocates the budget dollars to support personnel costs and the costs of necessary support items. This is compared with the on-board personnel strength to determine necessary actions. Over the last several years total personnel on board have been supported by a gradually increasing EFD workload, therefore there have been only minor changes in staffing. The problems occur at the ROICC Offices where in many cases, the workload can fluctuate by 50 to 100 percent within a year or two.

The next step, is to estimate the number of inspectors required at each ROICC. The estimated annual WIP is divided by the "rule of thumb" factor which relates estimated WIP

to manpower required. This provides a relative staffing among the ROICCs which must be adjusted to fit the manpower available. For example, NORTHDIV estimates that for every million dollars of MCON WIP 1.87 man-years (each man working 1760 hours per year) of effort is required and for every million dollars of O&M,N funded projects 2.29 man-years of effort are required. These rules of thumb have no apparent analytic basis other than general historic averages used as guidelines in the past. In addition, adjustments are made to account for some of the variables affecting the staffing requirements of each office. The variables considered by most construction division directors include number of contracts administered by each activity, nature of work (electrical, mechanical, etc.), qualifications of inspector, complexity of work, travel time required between job sites, capabilities of inspection staff and projected WIP trends for the next 6 months to a year.

The method for monitoring and reviewing staff requirements at ROICC Offices varies somewhat from one division to another. WESTDIV's policy is to review the staffing requirements for each ROICC Office every three months. The ROICC and the Director, Construction Division estimate the requirements separately based on an updated 6 month WIP projection. Wide variances in their estimates are discussed and negotiated. NORTHDIV makes a continuous review of the activity status report to check the variances between planned and actual workload as a measure of current and future staffing levels.

Each ROICC within a particular division, then, reviews his requirements and requests changes when he feels they are warranted.

E. STAFFING OF MILITARY PERSONNEL

The staffing of military personnel has been strongly influenced by a study, made under the direction of the Chief of Civil Engineers, to develop a "Zero Base" Corps Structure [Ref. 19]. While the current downward trend of the Corps size prevents implementation of the original plan, it is still updated and used as a basis for determining the ranks and numbers of officers to be assigned to any ROICC Office.

Within the ROICC area, the number of billets required were related to the workload, utilizing projected annual WIP for MCON and O&M,N projects. In order to do this, it was necessary for the board to determine a relationship between WIP and the number of officers of a particular rank structure. Analysis was done to determine what had been done historically by CEC Officers. From this data a staffing criteria was derived and used to develop the ROICC organizations.

F. ADVANTAGE OF WIP AS WORKLOAD FORECASTER

The main advantage of using projected WIP as a forecaster in estimating the NAVFAC construction program workload is its simplicity. Included in the total cost of every military construction project approved by Congress in their annual appropriation law is a fixed percentage factor for

SIOH. The use of a fixed rate in budgeting for SIOH costs, eliminates the requirement to analyze anticipated SIOH costs on an individual project basis. Thus as NAVFAC receives appropriated funds for new construction projects, the amount of funds available for managing these projects is easily determined. The EFDs as a result of this system receive their budget for construction management based on a direct proportion of their projected WIP. The number of inspectors that can be hired is easily determined by dividing the alloted funds by the average annual cost per inspector. By using this resource allocation procedure, minimal detail is required in justifying SIOH funds, it is easy to quantify the resources available for construction management, and it is easy to monitor actual SIOH costs in comparison with specified goals and objectives. It should be noted, however, that while simplicity is the basis of all good design, it does not necessarily equate with accuracy or optimality.

A major consideration in the evaluation of any system is a determination of how effectively the system can and will be used to achieve desired management objectives. It appears that projected WIP as a workload forecaster is useful as a management tool in resource allocation. There are two levels of workload and resource allocation that must be considered. First, there is the allocation of resources by NAVFAC to the EFDs and secondly there is the allocation by the EFDs to the field ROICC offices. These two problems should be considered separately due to the different

perspectives at each level of the organization. The NAVFAC allocation scope includes all the ROICC field offices supported by the six EFDs. By using sampling techniques, a projected WIP frequency distribution could be plotted and the mean or average workload value measured in man-years of effort per million dollars of WIP could be determined. When NAVFAC allocates resources to the EFDs on the basis of projected WIP, they in effect are using an empirical relationship between WIP and ROICC workload as being representative of total workload and allot resources accordingly. At the NAVFAC level, the WIP allocation procedure provides a sufficiently accurate estimate due to the averaging effect of the large quantity of projects and the wide range of contract categories. The WIP resource allocation method then is a useful tool at the NAVFAC level in aiding management in the achievement of its construction workload objectives.

G. WEAKNESS OF CURRENT RESOURCE ALLOCATION SYSTEM

The basic guide for forecasting the EFD construction workload has historically been the dollar value of construction work-in-place. Staffing requirements for projected WIP rely on estimates of total job costs and standard construction time schedules. While the empirical relationship between WIP and ROICC workload may provide an equitable base for allocating SIOH funds at the NAVFAC level, this is not considered to be true at the EFD level where resources are allocated to ROICC offices. The WIP allocation method

assumes an average work effort per unit of WIP. An individual ROICC office, however, will seldom have a construction workload that coincides with the NAVFAC average. Since the WIP method assumes average resource allocations, some ROICC offices will receive an overallocation while others will receive an underallocation of resources. Many important variables contributing to the ROICC workload tend to be overlooked when WIP is used as a single measurement of workload, thus, contributing to an imbalance in ROICC workload requirements and resources allocated.

A much more important consideration is the relevance of the workload measure. What is actually measured by WIP? The WIP factor is actually an output measure of the contractor. Theoretically, there is no direct relationship between this contractor output measure and the workload of the ROICC office. Consider also the SIOH factor in the allocation process. SIOH funds result from a budgetary process and are intended for use in providing the resources needed to manage the NAVFAC construction program. These funds are a portion of the input of the resource allocation system. In theory the WIP method attempts to forecast the input to one system based on the output of another system. The problems that arise stem from trying to treat a very vague relationship as a firm empirical set of rules. NAVFAC uses an empirical relationship between WIP and SIOH to allocate resources to the EFD's who allocate resources to the ROICC offices. The ROICC offices then take the resources allocated

and make them fit their workload requirements. When the workload is forced to fit the resources available, one of the following situations will usually occur. If more resources are allocated than necessary, there may be inefficiency and duplication of effort. If the ROICC workload requirements exceed the resources allocated, some important jobs may not be accomplished or resources will be supplemented by others such as the Naval Activity Public Works Department or the customer activity. A review of ROICC activities indicates that these additional supplements to SIOH are not recorded, therefore, the SIOH costs do not accurately reflect ROICC workload. The fact is that the WIP/SIOH relationship alone is not a sufficient basis for forecasting construction workload requirements and allocating resources. Consequently considerable judgment is required to make this system work. The weaknesses inherent in this type of system are that many important factors are overlooked, consistent and equitable resource allocation is virtually impossible, and misallocation risk is increased.

A simplified method of resource allocation is desirable so long as the simplicity is not achieved at the expense of accuracy. The WIP method is simple and easy to use, but the omission of variables which strongly influence workload can result in biased allocations and improper balance of construction workload with resources. Implicit costs are incurred when an erroneous estimate leads to consequences which are costly. Consider the projected WIP target as a

basis for hiring a certain number of inspectors. If this estimate is unrealistically high, SIOH income will be insufficient to cover the cost of inspection. If the WIP estimates are low, some inspection work will be slighted and the government may not receive the full construction value expected. Moreover there is a certain amount of risk involved when significant variables influencing workload are overlooked or disregarded. Once again this results in some jobs being overstaffed with resultant inefficiencies while others are understaffed.

The resource allocation manager must assess his preferences toward the risks involved by considering the chances of making errors in resource allocation and thus incurring their implicit costs. Presently there are few quantitative measures to evaluate the impact of variables such as quantity of contracts, nature of construction work, dispersion of projects and motivation of inspectors. Consequently, judgment and experience are presently the prime means of assessing preferences towards risks and modifying the allocation of resources. Additional quantitative measures are needed to equip the resource manager with managerial tools that will enable him to consistently and equitably cope with the complex problems in an environment where competition for available resources is acute.

Both NAVFAC and the EFDs use a historical data base as a means of estimating man-years of effort required per million dollars of WIP and dollar cost per man-year of effort. The

results of past events can be valuable if information from these events is used to identify problem areas requiring increased management attention. When historical data is used as a basis for forecasting future requirements indiscriminately without the benefit of quantitative analysis, the results may be a continuation of past mistakes and misallocations.

The "S" curves used at both the NAVFAC and EFD resource allocation levels have the same inherent weaknesses discussed above. These curves are used to distribute the projected WIP over a predetermined time duration. The basic weaknesses are: (1) WIP alone is not directly related to the ROICC's workload, (2) there is no indication that all significant variables influencing the ROICC's workload have been considered, and (3) the accuracy of the WIP distribution function of curves and the estimated construction duration function based on dollar value of contract appears to be unvalidated.

V. IDENTIFICATION AND ANALYSIS OF VARIABLES

A. VARIABLES RELEVANT TO RESOURCE ALLOCATION

The EFD resource manager is frequently faced with decisions among allocation alternatives. These decisions may be fairly complex in terms of possible choices or they may be simple. Regardless of the degree of complexity of a particular decision, the resource manager in seeking to optimize resource allocation needs to obtain all the information relevant to the alternative choices. This information will include, very importantly, cost data such as projected dollar value of WIP. It should also include many other variable factors which may be even more important than WIP in terms of relevance to the allocation process. The most significant variables influencing the administration and implementation of NAVFAC's construction program are discussed below.

1. Work-in-Place Variable

This variable is a measure of the contractor's output, however, it is being used to forecast future SIOH revenue which is an input to the NAVFAC construction program workload. WIP is a measure of the dollar value of work completed by a contractor and represents a legal cost to the Government. The analysis of costs according to their behavior pattern with respect to changes in workload greatly aids the managerial functions of planning and allocating resources.

To meet the needs of management, however, the costs that are being considered in the cost-volume type relationship must be relevant and significantly related to the volume measurement. The question that must be asked is, "what workload is being measured with respect to WIP costs?" The WIP costs are more directly related to the contractor's workload than they are to the EFD's contract administration. When a cost-workload relationship is established and used without the existence of a significant bona fide relationship, the system tends to force the workload to fit the costs. While a direct relationship between the EFD's construction workload and the dollar value of WIP is not known, the WIP variable continues to be the prime factor used in the allocation of resources to the ROICC offices. Consequently, the discussion of other variables will include comparisons of different situations where it is assumed that the dollar value of WIP is constant in an effort to show the impact of these other variables on actual workload.

2. Quantity of Contracts Variable

The work-load of various ROICC offices with the same total dollar value of WIP, will be different if each ROICC has a different number of contracts to administer. Related to the number of contracts are factors such as: volume of contract paperwork, percentage of available inspection and contractor surveillance time lost due to traveling between jobs, quantity of liaison contacts, and quantity of contract start-up and close-out work. Consider two ROICC offices

with the same projected total dollar value of WIP but the first with twenty contracts (each over $10,000) and the other with only one contract. The administration of each contract requires a public advertisement of bid opening and the issuing of bidding data, pre-construction conferences, liaison with both a contractor and customer during construction, the processing of contractor progress payments and numerous contract close-out functions. It can easily be seen that the ROICC office with twenty contracts will have a much different workload than the ROICC office with only one contract even though the total dollar value of WIP is equal for both. The actual number of contracts being administered by a ROICC office is easily obtainable and a cost-volume relationship between quantity of contracts to be administered and the contract administration workload is considered feasible. This relationship once developed would be useful in forecasting future workload as a function of this variable.

3. Weather Variable

Weather is becoming a less significant problem to the construction contractor due to improved technology and specialized materials for severe weather conditions. The overall effect on the construction administration workload, however, is significantly influenced by the weather variable. New technology usually requires more sophisticated equipment which is more expensive. Also specialized materials are more expensive. Severe weather conditions change the

frequency of inspections and requires additional safety regulations for the contractor to follow and the Navy inspector to monitor. For example, concrete may not be placed on some jobs if the temperature exceeds either a minimum or maximum level. At extreme low temperature there is a freezing problem and at high temperatures a concrete flash set problem. In areas where temperatures may fluctuate beyond the limiting ranges, additional workload is placed on the inspectors. An area with frequent, gusty, high winds also has additional safety regulations which must be monitored. Another factor to be considered when weather conditions deviate from a normal comfort range is increased inspector fatigue. This results in reduced inspector output thereby decreasing effectiveness.

Weather data is available for all areas where the NAVFAC construction program is being administered and therefore a weather factor could be quantified and applied to the forecast of an EFD's construction workload. One means of application to the forecast would be the modification of the "S" curves to account for areas with adverse weather conditions.

4. Quality of Plans and Specifications Variable

Plans and specifications are the major line of communications between the Government and the contractor. When communications break down problems usually occur. Time is a factor here as operational demands frequently require rapid completion of the plans and specifications,

hence causing an increase in the number of inaccuracies. Any time the plans and specifications are difficult to interpret a large percentage of the inspector's and ROICC's time is involved in discussion with the contractor, design agent and perhaps even legal counsel. Also when the plans and specifications are poorly written, the completion date may be extended and the contract price increased by the change order process. There are many other hidden costs in change orders: the lost time of ROICC construction representatives, inspectors and engineers while negotiating changes, time of office staff for drafting change orders and related correspondence, and delay in WIP rate if extensive redesign is necessary and/or the work is not authorized until the completion of negotiations.

Quantification of this variables' impact on the construction administration workload may be difficult. One basis would be by historical analysis of change orders and the increased ROICC staff work related to these changes. There would still be a problem, however, in identifying in advance which plans and specifications are inadequate in quantity and quality of detail.

5. Inspector's Capability and Motivation Variable

Studies have shown that many factors affect visual inspection performance with the attitude of the inspector being by far the most important. The reduction of inspection coverage due to an inspector's ineffectiveness and lack of motivation is costly. It means that the ROICC or construction

representative will have to spend additional valuable time straightening out difficulties and overseeing the inspectors daily work. When ROICCs or construction representatives don't have the extra time for this, it means unsatisfactory construction work may be undetected prior to acceptance.

Training programs may be used to increase the effectiveness of inspectors. It should be noted, however, that training is accomplished during normal work hours and additional personnel may be required during training periods.

Inspectors could be evaluated based upon a systematic appraisal of job assignment, personal qualifications, performance in present job, progress made in job performance, and potential level of development. This information could be keyed to several significant performance variables and used by the EFD resource manager in attempting to allocate the right people to the right job at the right time.

6. <u>Material Testing Support Variable</u>

The requirement to use Contractor Quality Control (CQC) has been extended to all contractors over $10,000 and material testing support (a function of CQC) is a primary responsibility of the contractor. The Contractor Quality Control program would eventually reduce the significance of this variable. This variable may have some affect on the ROICC's workload but its influence has not been adequately measured.

7. Quantity of Labor Variable

Quantity of labor in a contract could be considered as a measure of workload in place of WIP since there are cases in which the greater portion of the contract is expensive equipment which may require little inspection time. There is some indication that labor-hours would be more accurate than dollars of WIP as a means of forecasting the construction program workload. A study should be done to examine this possibility.

8. Contractor Quality Control Variable

NAVFAC introduced the Contractor Quality Control Program in March 1970. The influence of CQC on the resource allocation problem has varied from none to a major consideration depending on how the various levels of the NAVFAC organization differed in their application and execution of the program. CQC is intended to be an integral part of the Navy's construction quality control program. The Navy Construction Quality Control Program is a single system with the contractor's quality control just one of the three basic elements. The other two elements are Navy inspection and Navy surveillance of CQC. Inspection is a strict, close or critical examination of construction work to determine compliance by the contractor with plans and specifications. Surveillance differs from inspection in that it is a close watch or observation of the contractor's inspection system to insure that it is functioning properly. All three elements have a direct influence on each other as well as being

related to other variables such as contractors' reliability and inspectors' capability and motivation. The results of surveillance will indicate the frequency that inspections should be scheduled. The results on inspections will indicate how well the CQC is functioning and whether additional surveillance is needed. The CQC plan when functioning properly may reduce the total Navy inspection effort required. The increased role of surveillance due to CQC may change the inspector/construction representative mix since the pure inspection requirements should be reduced. The qualifications of the person doing surveillance will normally be greater than those of an inspector since surveillance requires the ability to make sound judgmental decisions vice decisions based strictly on pass/fail standards. This system will work but care should be taken in the selection of Navy construction representatives since they must work very closely with the CQC representatives and if the construction work is to progress expeditiously, an atmosphere of mutual cooperation rather than one of adversity must be developed.

CQC, like other variables identified and discussed in this section, cannot be isolated by itself. The nine most common problems encountered in the implementation of CQC include apathy of OICC/ROICC personnel, a function of the inspector motivation variable, and apathy by the contractor's top management, a function of the contractor reliability variable. The number one problem is "inadequate description of CQC requirements in the specifications"

which is a direct function of the plans and specification quality variable [Ref. 14]. The resource manager should know all his construction representatives or at least have available to him an information file on characteristics of each construction representative so that he can change or augment specific workload requirements with the right type of people to correct CQC problems. If CQC problems are to be minimized, potential CQC problems must be diagnosed early and treated through personalized resource allocation.

9. Reliability of Contractor Variable

The contractor's ability to supervise his own work, coordinate the work of his subcontractors, foresee and forestall field problems, and in general maintain a job that is continuous and progressive with a minimum of delays can contribute much to the actual ROICC workload requirement. Quantifying the contractors ability in terms that would predict how a ROICC's workload would be affected by a particular contractor could be accomplished by evaluating all potential contractors on key performance elements. This information could then be stored in the Construction Management System data bank and modified any time changes were documented. This data could then be used in the preparation of select bidders lists for critical jobs and could be used as an aid in forecasting changes in ROICC workload requirement necessitated by a particular contractor being awarded a contract.

The Bergman study used a questionnaire to solicit responses from personnel involved in construction management at five EFDs and ten ROICC field offices. Responses to a question regarding how frequently a "bad contractor" was encountered indicated this frequency to be 15 to 20% of all contracts [Ref. 5, p. 34]. This study further showed that the low bidder system frequently leads to poor quality workmanship, especially from marginally reliable contractors [Ref. 5, p. 9]. By maintaining contractor profiles in the Construction Management System data bank, the marginally reliable contractor could be identified early and additional construction representatives could be assigned to help insure satisfactory work. A few highly motivated professional construction representatives at each EFD could be available for assignment to temporary additional duty at various ROICC field offices when a marginally reliable contractor is awarded a contract. Once the construction has gotten underway and the local construction representatives have been advised of potential trouble spots, the construction specialist would return to the EFD and be available for assistance to other ROICC field offices. It is postulated that increased SIOH costs from this procedure would be offset by increased end-product quality. One would further expect that this procedure would reduce construction time overruns by problem contractors.

Every contractor awarded a government construction contract is required as a minimum to perform (1) a preparatory inspection, (2) initial inspection and (3) a follow-up

inspection. The preparatory inspection is performed prior to the beginning of any segment of work and includes a review of contract requirements, a check to assure that provisions have been made to provide required control testing, and a physical examination of materials and equipment to assure that they conform to requirements. The initial inspection includes the actual performance of all scheduled tests and an examination of the quality of construction workmanship. The follow-up testing includes continued testing and examinations to assure continued compliance with contract requirements. An evaluation of how well the contractor performs and documents these inspections would provide a basis for predicting changes in inspector and construction representative staffing levels. It is recognized that the need for staffing adjustments to compensate for contractor reliability factors could not be made until after a contract award, but for large jobs requiring several months to mobilize, this would be sufficient time to allow minor changes. For shorter duration jobs, staffing changes that were required could be facilitated by temporary additional duty assignments.

In staffing for any project, the resource manager should avoid functional emotionalism. That is, the resource manager should not consider staffing a project at minimal level just to get his part of the job complete but should be concerned with adequate staffing to insure a quality end-product, thus avoiding future excessive government funded O&M costs. It is for this reason that a contractor's performance should be documented and made a part of the

construction management system and when additional contractor quality control surveillance or construction inspection is indicated, these changes could be incorporated into the resource allocation plan.

10. Local Labor Environment Variable

The local labor environment is a variable that exerts both direct and indirect influence on the ROICC's construction workload and relates very closely with the reliability of the contractor. The Armed Services Procurement Regulation (ASPR) 18-704.8 requires that regular checks be made on the contractor to assure compliance with contract labor standards. Where the contractor's labor relations have been notorious, the ROICC's workload in the labor relations area will be considerably higher than with a contractor with an outstanding labor record. ASPR requires employee interviews to determine classification and rate of pay, on-site checks of type and classification for work performed, payroll submittals, and review of CQC reports to insure consistency with personnel data. The percentage of RIOCC workload contributed by these particular tasks is directly related to the number of employees the contractor has on the job site. Since the number of employees hired by a contractor is not directly proportional to the dollar value of a contract, the projected WIP on which SIOH income is earned gives no indication about how labor intensive a project will be. An additional column in the projected WIP reports showing the percentage of labor

dollars in a contract would aid the resource manager in determining labor related construction workload requirements.

Additional factors in the labor environment that must be considered are: (1) labor unrest with potential sabotage, (2) local labor union's propensity to strike with resultant work stoppages, (3) labor market saturation, (4) hiring time lags and (5) tendency for grade level creep without noticable increase in skill thus increasing SIOH costs. Labor unrest and a labor union's propensity to strike, tend to delay work thus lengthening construction time and reducing the rate of SIOH income earned. Labor market saturation can also result in increased costs and a decrease in expected SIOH income earned for the period. Consider as an example the Alaskan oil pipeline project. This high priority job will require many pipefitters and may create a pipefitter demand that exceeds the supply. As this labor market demand remains unfilled, two reactions may occur. Job costs will increase from higher wages required to attract the scarce tradesman and use of high overtime pay will increase to compensate for shortage of manpower. Additionally job extension with reduced WIP rate may result from labor shortage.

Interrelated with labor market saturation is the hiring time lag. As additional workload requirements are identified, it must be realized that new hires by the resource manager can not be obtained instantly. In many cases, it may take up to six months to hire new inspectors and

construction representatives. This makes early identification of future workload requirements very important.

The local labor environment then has two significant influencing effects. The direct effect is related to percentage of labor in total contract cost and in the time delay required for increasing the ROICC staffing level through new hires. The indirect effect is manifest in delayed earnings for SICH resulting from construction extensions due to poor labor relations or labor market saturation. Both effects must be considered by the prudent resource manager and future staffing levels adjusted accordingly.

11. Job Dispersion Variable

Activities covering large areas such as test ranges and Naval Ammunition Depots suffer extensive lost time due to travel. A scattering of small construction projects throughout a geographic area assigned to a single ROICC field office may have the same dollar value of projected WIP as a single large job adjacent to its ROICC field office. Assuming the construction workload was the same in both cases (valid only if WIP was a direct measure of workload), there would still be inequalities in resource allocation if both were treated as equals due to equal projected dollar value of WIP. The difference being the adverse affects on efficient use of available resources (inspectors, vehicles, gas, and field offices) due to extensive traveling required between inspections and surveillance of CQC in the case of many scattered small projects. When travel lost time is

not considered in the allocation of resources, the ROICC usually assigns his staff to the resolution of urgent problems on the construction critical path. Less urgent quality assurance inspections and surveillance of CQC get slighted by the amount of lost time due to travel. The anticipated net result in this case would be a decrease in end-product quality. In order to offset this, when the average lost time per week due to abnormal travel requirements between job sites exceeds a predetermined amount per week, an additional inspector should be assigned. Additionally the actual travel requirements should be analyzed on an individual ROICC office basis to determine adequate vehicle and vehicle maintenance support funds.

This variable must also be considered with the variable associated with the number of contracts. In the example above, the case with many widely dispersed job sites was also composed of the greatest number of contracts. Dispersion usually becomes a problem when there is more than one job, each of which is too small to utilize one inspector or construction representative on a full time basis. The combined effect of dispersion and number of contracts must be considered if balancing workload with requirements is to be accomplished.

12. <u>Nature of Work Variable</u>

A study of the nature of work to be accomplished includes factors such as complexity of actual construction, degree of command interest in the project, and funding

source. An extreme example of complexity differences would be the construction of a pure water system for a nuclear reactor and the construction of sidewalks in a government housing area. As the complexity of construction work changes, the inspection workload changes and hence the staffing requirement will change.

The degree of command interest in a project is a variable that is almost impossible to quantify, yet, it is frequently a problem, especially with non-Navy jobs. The greater the degree of customer command interest, the greater will be the degree of customer job surveillance. There should be only one person telling the contractor what to do. This is frequently a customer conflict area since they innately feel it is their right to tell the contractor what to do. Since the OICC or his duly designated representative is the only official contact between the government and the contractor, the ROICC personnel must spend much valuable time providing liaison between the customer and the contractor. Everytime there is an increase in command interest in a job, there will be a corresponding increase in required customer liaison work.

A third important factor to be considered is whether the project is new construction or remodeling and alteration work. The McClellan study combined field measurement work with activity sampling and developed a listing of in-place unit inspection times. The inspection times are for new construction on-site work and include time for indirect

productive and non-productive activities, but do not include off-site travel time. McClellan concluded by saying the time values would have to be doubled for use with remodeling and alteration work [6, p. 12]. The NAVFAC Study Topic 69-3 considered operation and maintenance funded work to require 1.5 times as much inspection effort as that required for new construction work. The SOUTHDIV ROICC Handbook states that the construction administration workload for operation and maintenance funded projects is twice that for new construction work. In either case, there is a considerable difference between the ROICC's construction workload generated by new construction and that generated by remodeling and alteration work. Factors contributing to the increased workload on remodeling and alteration jobs are: (1) vagaries in as-built conditions, (2) operational constraints which increase administration effort and (3) the dynamic condition on the job site. The wide variation in actual workload based on the nature of the work to be accomplished makes this a very important variable to quantify prior to making changes in resource allocations.

13. Construction Risk Variable

There are a number of construction jobs that are considered to have a high risk of failure if improper procedures are followed. Jobs that fall into this category require continuous inspection and thus are in sharp contrast with the normal spot-checking type of inspection. Consider a large pile driving project and a project to construct a dirt

perimeter road and install several miles of perimeter fences. The pile driving project will require continuous inspection with a pile record kept for each pile which is incorporated into the permanent structure. The perimeter road and fence job may have a high estimated budget cost due to extensive clearing, grubbing and excavation but still only require a minimal spot-checking inspection. High risk jobs in this category may also require enforcement of additional safety regulations which must be monitored. The percentage of high risk construction at each ROICC field office will certainly contribute to the amount of inspection effort required and hence the number of inspectors required.

14. <u>Construction Time Phasing of Adjacent Jobs Variable</u>

This is a relatively minor and virtually uncontrollable variable, but is worth mentioning since it could influence the workload in area ROICC offices. The greater organizational depth and spread of a large ROICC office provides the ability to respond to construction workload with a more efficient utilization of staffing and material support resources. This would result in a higher dollar value of WIP per inspector without actually changing the workload per inspector.

15. <u>Temporary Inspector Move vs. Temporary Overstaffing</u>

The commencement of new construction at any ROICC field office is on a random rather than deterministic basis. This can be attributed to the existing military construction planning, programming and budgeting (PPB) cycle. Projects

are approved and funded by the annual authorization and appropriation laws. EFDs receive funding for a large number of projects at one time and tend to award all contracts just as soon as plans and specifications are completed. This tends to create peaks and valleys in the individual ROICC's construction workload. The resource manager then must evaluate future workloads, considering cost trade-offs between temporary relocation of some inspectors as compared with temporary overstaffing. It is very unlikely that the PPB system will change and neither will the pressure from customers to get contracts awarded just as soon as they are funded. The significant factor remaining is the accuracy of future workload predictions. In order for the resource manager to make an intelligent decision on relocation vs. overstaffing he must be able to make reasonably accurate future workload predictions taking into account the significant variables in this section and their influence on workload.

16. <u>Contract Format Variable</u>

The format of a contract will be determined usually by the estimated dollar size of the contract. The three basic contract forms are: informal (under $2,000), short-form (under $10,000), and long-form (over $10,000). A contract may also be awarded on an actual contractor cost plus fixed fee or negotiated price basis. The informal and short-form contracts have less stringent paperwork requirements than the other contract form, however, these contracts

are frequently O&M,N funded jobs, which due to the nature of the work, require an increased inspection effort. The net result is that office administration costs may be reduced on informal and short-form contracts while the inspection workload may be increased.

B. SUMMARY OF VARIABLES ANALYZED

Projected WIP is the primary basis for resource allocation at both the NAVFAC and the EFD levels. To date there is no known relationship between the contractor's output (WIP) and the budgetary input (SIOH) to the NAVFAC resource allocation system,which allocates resources on the basis of an empirical relationship between vaguely related input and output measures. The result is that construction administration requirements are forced to fit the allocated resources.

The variables associated with quantity of contracts, weather, nature of construction work, job dispersion, contract format, and level of construction risk are considered to be quantifiable, relative to their impact on workload. This would enable a basic resource requirement to be established. This basic requirement could be further modified as required after reviewing the contractor reliability profile and matched with desirable inspector motivation and capabilities factors. To quantify these variables, it will be necessary to establish a classification system that will facilitate the identification and evaluation of significant

variables and develop a model for relating the quantified factors to construction workload requirements.

VI. CLASSIFICATION SYSTEM FOR CONSTRUCTION PROJECTS

A. OBJECTIVES OF A CLASSIFICATION SYSTEM

Many variables contributing to the ROICC's overall construction workload requirements can be described in terms of quantifiable descriptors such as: dollar value of WIP, number of contracts, hours of lost time per week, and man-years of effort. Weighting factors must be applied to these descriptors based upon how much each contributes to the overall workload. A well designed classification system for construction projects will contribute to consistency in the application of weighting factors. Objectives of this classification system will include: provision for accurately identifying all construction projects influencing workload, provision for identifying major categories of construction work, be relatively easy to understand and use, and be adaptable for computer programming.

B. PROPOSED CLASSIFICATION SYSTEM

The proposed classification system, which satisfies the objectives presented above, will use part of the Navy category code series which is based on the Department of Defense (DOD) category code structure. This structure is used in connection with Shore Activities Programs to ensure uniformity in the area of budgeting, planning and programming, real property management, design, construction, maintenance, and record keeping. All buildings, structures, and utilities

are categorized within the structure of the three digit DOD basic category codes. Since these codes are already widely used, their adaptation to a classification system related to the ROICC's construction workload requirements should cause minimal consternation.

The classification system uses a five digit alpha-numeric code with the first two digits identical to the first two digits of the basic DOD categories. The remaining three digits are alphabetic codes identifying the nature of work, relative risk level, and contract format. A sample of a composite code for construction workload classification is as follows:

13NHC	Automatic Communication Switching Center
1	Facility Class (Operational and Training Facilities)
3	Category Group (Communication and Navigational Aid)
N	Nature of Work (New Construction)
H	Relative Risk Level (Higher than normal inspection level)
C	Contract Format (Long Form)

The DOD facility class and category group from which the first two digits of the code are obtained is as follows:

100	Operational and Training Facilities
110	Airfield Pavements
120	Liquid Fueling and Dispensing Facilities
130	Communications, Navigational Aids and Airfield Lighting
150	Waterfront Operational Facilities
200	Maintenance and Production Facilities
300	Research, Development, and Test Facilities
400	Supply Facilities
500	Hospital and Medical Facilities
600	Administrative Facilities
700	Housing and Community Facilities
800	Utilities

NAVFAC P-72, Category Codes for Real Property, Navy, contains the complete cataloging of Navy codes and detailed guidance in classification procedures [Ref. 11]. The third digit of the DOD category series is used for describing the basic category by use within the category grouping and is not considered necessary for use with the construction workload classification system. When the general facility code will suffice for project identification, the second numeric code will be zero. Three additional alphabetic codes are required, however, to supply all the information needed in the workload classification code. The first alphabetic digit will distinguish between new construction (N) and rehabilitation work (R). The second alphabetic digit identifies relative risk level. Risk as used here relates to the quantity of inspection effort required and would be coded high (H), medium (M), or low (L). The last digit identifying the contract format would be coded informal (A), short form (B), and long form (C).

While it is possible to describe and assign construction projects to distinct classification pigeonholes, there will always be a number of effects which cannot be measured or evaluated directly. Resource managers evaluating the diverse effects of each workload classification category will have different subjective preferences as to the overall value assigned. The individual preferences have an inherent vagueness which cannot be explicitly expressed. A purely quantitative assessment of all factors contributing to

construction workload at any level is unrealistic. Difficulties encountered in the system will arise generally from an unwillingness or inability to see the problems, to share in the diagnosis or to be actively involved in generating solutions. However, when the classification system is used as a management tool, it could become very useful.

C. OTHER CONSTRUCTION CLASSIFICATION SYSTEMS

Several additional construction classification systems have been considered but their shortcomings seriously curtail their usefulness. The major systems considered were by funding source, by construction category, and by dominant trade or engineering discipline [Ref. 13]. Each of these systems by itself was limited in scope and would not satisfy the classification system objectives.

VII. SUMMARY AND CONCLUDING REMARKS

In the previous sections we examined current methods and procedures for resource allocation by NAVFAC and the EFDs to ROICC offices. The environment in which this allocation process takes place was described so that a better understanding and appreciation of the allocation problem could be achieved. Also a number of variables were identified and their impact on the ROICC's construction administration workload discussed. Finally a construction project classification system was proposed as a means of relating specific variables with the ROICC's construction administration workload. The information obtained from identifying and quantifying these variables could then be used by the resource allocation manager in allocating resources to the ROICC offices.

An important NAVFAC objective as stated at the onset of this thesis is to ensure the availability of shore and fixed ocean facilities necessary to support the Navy at the best balance between requirements and resources. It is usually relatively easy to state desired objectives in terms such as optimizing resource allocation. Determining how to achieve these objectives effectively and efficiently, however, requires not only creative direction, but also a need for definitive detail. Assuming that the problem is not exacerbated by ineffective objectives, one must now define and

determine effective alternative methods to achieve these objectives.

A review of historical events indicates that the process of creativity is not necessarily rapid and does not always come at low cost. For this reason both short-range and long-range alternatives will be discussed.

A. BASIC PROBLEM AREAS

The empirical relationship between WIP and SIOH indicates that a cost-volume relationship exists between a contractor's output and the ROICC's workload. If there was a valid direct relationship between the ROICC workload and projected WIP, the current allocation procedures would adequately provide a single action approach to achieving the prime NAVFAC objective. Unfortunately there is no known direct relationship between the dollar value of the contractor's workload and the cost of tasks required for administration of the construction work. Resources allocated on this basis tend to cause a forced fit between the ROICC workload and resources supplied. Neither the tasks nor the time required for administration of a contract appear to be clearly defined. NAVDOCKS technical publication, Inspection of Construction Contracts [Ref. 4] does provide general requirements and guidelines, but it is an old manual that has been antiquated through technological improvements and mandatory CQC requirements.

Although difficult, it is considered feasible to quantify the impact of significant variables on the ROICC's workload. A basic problem, however, is that there are no performance standards for construction administration tasks which can be used to properly determine the estimated man-hours of effort required. The study group for NAVFAC Topic 69-3 [Ref. 18] and Mr. R. E. Bergman of the Naval Civil Engineering Laboratory [Ref. 5] both made strong recommendations for the development of performance standards prior to any further attempt to improve the allocation system. In another study, Mr. McClellan [Ref. 6] attempted to derive performance standards for ROICC Long Beach as a means of analyzing workload. The need for these standards still exists.

B. SHORT-RANGE ALTERNATIVES

The length of time required to develop an estimation procedure based on engineered performance standards and to make the related changes in the allocation system suggests that investigation, of an interim method of estimating ROICC workload would be appropriate. A number of studies have attempted to derive a model similar to the estimated WIP system, but have replaced estimated WIP as the basic estimator. CDR George Bednar developed a "Staffing Model for the ROICC Philadelphia Office" [Ref. 22] which estimated the time required to perform specific tasks for an average contract. LCDR Eugene W. Thomas' study "OICC/ROICC Staffing Analysis-Overhead Positions" [Ref. 21] related the staffing

of all the NORTHDIV OICC/ROICC Offices to the number of contracts handled. The study group working on the "Billion Dollar Study", NAVFAC Study Topic 68-8, [Ref. 13], proposed a method for subdividing a contract into basic elements called "construction phases" and relating the inspection required to the material used in each phase. These three cases each considered an alternate basis for determining a relationship between ROICC workload and resource requirements. Although another variable may be a more appropriate estimator than projected WIP, the total construction administration workload cannot be adequately determined by evaluating just one variable.

There appears to be a need for a model to relate all the pertinent variables, as no single variable will provide an adequate forecast of workload requirements. The use of a single variable as a "ball park" guide forces the resource manager to weigh all the remaining identifiable factors, relying solely on his experience and judgment. A model, by providing a frame of reference, allows a precise statement of the problem in contrast to a verbal description. It forces the identification and selection of the relevant factors, some of which can be dealt with quantitatively while others simply provide a means of applying the judgment and experience of resource managers more systematically.

The short-range recommended alternative is to develop a factor table which could be used in translating identifiable construction workload variables into a quantitative form

such as man-years of effort. It is further recommended that a mathematical model be developed to relate these quantifiable variables to the actual construction administration workload. This allocation system would basically be a modified WIP system with all the significant modifiers included in the model. It is recognized that a modified WIP system does not resolve all the previously discussed disadvantages of the procedures currently in use. It does acknowledge, however, that the WIP system is the only allocation "game in town" as far as SIOH revenue is concerned. Also a mathematical model used to modify the projected WIP per man-year of effort ratio will provide a more consistent and equitable resource allocation system than the WIP rate method by itself. Included in this short-range alternative is the recommendation to update the "fair weather curves" and include a set of abnormal weather curves for use where weather variations have a significant impact on the ROICC's construction administration workload. Once this sytem is implemented, there should be a frequent monitoring of factors relating variables to workload and changes made anytime significant variations can be validated.

C. LONG-RANGE ALTERNATIVES

The most appropriate procedure for linking programmed contracts and the necessary man-years of effort seems to be to develop a system for estimating the man-hours of inspection and administration required for each contract.

This would necessarily include the man-hours of overhead required by both the ROICC, the EFD, and NAVFAC. The overhead requirement could be calculated by a series of desk audits, but the inspection process would require a major study to determine the most cost-effective inspection procedure on which to base the performance standards. A precedent has been set by the use of Engineered Performance Standards for the estimation of alteration and maintenance work in public works departments of naval activities. The complexity of both areas is similar.

An additional long-range alternative involves a capital budgeting concept. Objectives should be developed directly relating the resources available to what work is actually required. A pilot study designating one EFD as a prototype for evaluating the feasibility of a new allocation system should be considered. Under this pilot study program, the selected EFD should be allowed to operate for three years to develop actual cost data in administering its construction program. This EFD should be capitalized for basic fixed costs required to establish and maintain field offices plus variable costs required to administer contracts. Provision should be made for recording all costs (both labor and non-labor) without risk of penalty if budget is exceeded. A periodic audit of the costs and procedures utilized would be highly beneficial for evaluating the pilot study program. Upon the conclusion of the three year pilot study program, the data collected could be analyzed for possible major allocation system revisions.

A final alternative to be considered for long-range application is computer-aided allocation decision making. Presently there is very little computer application in the resource allocation system. The EFD/MIS is being utilized for mechanistic tasks such as the projected WIP report. Applications using solely algorithmic type of programs for performing quantitative functions do not utilize the full potential of the computer. The EFD/MIS could be used as the basis for developing an on-line, interactive adaptive decision system using a computer program which relies on a sound and thorough analysis of the total environment encompassing the allocation problem. This system could have great appeal and usefulness to resource managers partially because it would not require a basic structural change in the manager's role. He would not feel threatened by a supposedly optimizing mathematical model. On the contrary he remains the focus of the decision-making process, with a high premium placed on his judgment and intuitions.

APPENDIX A

KEY PERSONNEL CONTACTED

CDR Miller Andress, CEC, USN, NAVFAC

Mr. D. H. Bailey, NORTHDIV, Construction Division

Mr. R. E. Bergman, Civil Engineer Lab, Port Hueneme

Mr. Robert J. Carns, Asst. Resident Engineer, Monterey Resident Office, U.S. Army Engineer Dist., Sacramento

Mr. S. Dana, WESTDIV, Head, Organization and Manpower Branch

Mr. J. R. Dumser, NORTHDIV, Director, Construction Division

Cpt. C. Hilton Dunn, Project Officer, Monterey Resident Office, U.S. Army Engineer Dist., Sacramento

LCDR S. D. Frankum, NORTHDIV, Acquisition Coordination Officer

Mr. R. Hasse, NAVFAC, Headquarters ADP Systems Branch

Mr. E. L. Hughes, WESTDIV, Director, Construction Div.

Mr. A. F. Malloy, NAVFAC, Resources Management Branch Head

Mr. McNeely, Chief, Construction Division, Office of the Corps of Engineers

Mr. J. G. Mills, NAVFAC, Head Program Coordination Office

Mr. J. W. Rhodes, NAVFAC, Headquarters ADP Systems Branch

Mr. J. Susha, FACSO, Manager, EFD Military Construction Branch

CDR Thomas N. Tate, CEC, USN, Instructor, OR/AS Department, Naval Postgraduate School

Lt. Taylor, WESTDIV, Acquisition Coordination Officer

CDR Jack Tolliver, CEC, USN

Mrs. L. M. Walker, WESTDIV, Asst. Head Analysis Branch Acquisition Department

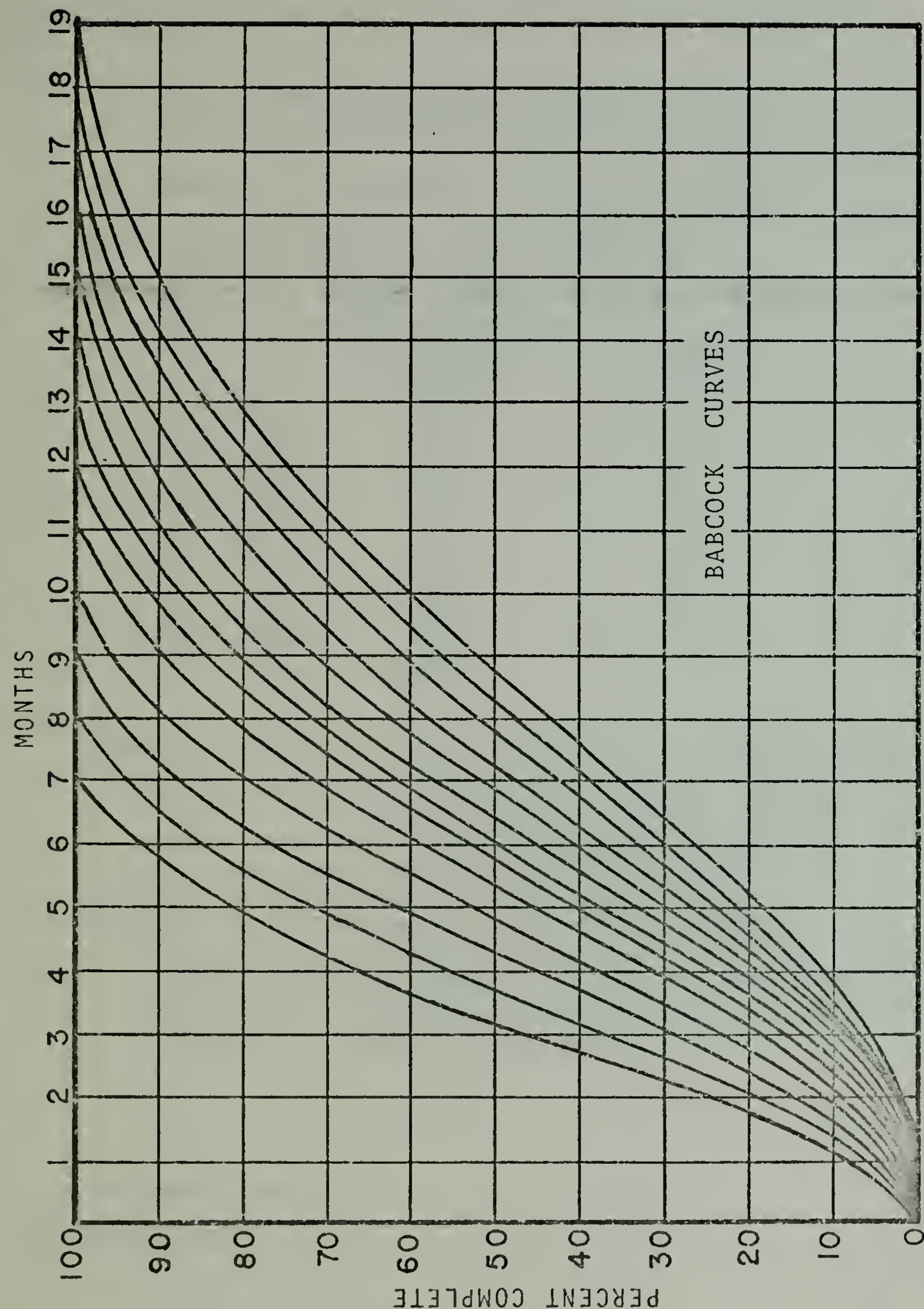
TABULATION OF ACCRUED COSTS BY MONTHS
FOR
MEAN FAIR WEATHER CONDITIONS

PERCENTAGE COST IN PLACE
CUMULATIVE BY MONTHS

																								100	1	19
																						100	1	99	2	18
																				100	1	99	2	97	3	17
																		100	1.5	99	2	97	3	94	4	16
																100	2	98.5	2.5	97	4	94	4	90	4	15
														100	2	98	3	96	4	93	4	90	5	86	5	14
												100	2	98	3	95	4	92	5	89	6	85	6	81	6	13
										100	3	98	4	95	5	91	5	87	5	83	7	79	7	75	7	12
								100	4	97	6	94	6	90	6	86	6	82	7	76	7	72	7	68	8	11
						100	4	96	6	91	7	88	7	84	7	80	8	75	8	69	8	65	8	60	8	10
				100	5	96	7	90	8	84	8	81	9	77	9	72	9	67	9	61	9	57	9	52	8	9
		100	6	95	8	89	9	82	10	76	11	72	10	68	10	63	11	58	10	52	9	48	9	44	9	8
100	7	94	10	87	10	80	12	72	12	65	12	62	12	58	12	52	11	48	11	43	10	39	9	35	8	7
93	12	84	12	77	15	68	15	60	15	53	13	50	13	46	12	41	11	37	10	33	9	30	8	27	8	6
81	15	72	16	62	16	53	16	45	14	40	13	39	13	34	12	30	11	27	10	24	8	22	8	19	7	5
66	21	56	19	46	16	37	15	31	13	27	12	24	10	22	10	19	9	17	8	16	8	14	7	12	6	4
45	22	37	19	28	15	22	12	18	9	15	8	14	8	12	7	10	6	9	6	8	5	7	4	6	3	3
23	16	18	12	13	9	10	7	9	6	7	5	6	4	5	4	4	3	3	2	3	2	3	2	3	2	2
7	7	6	6	4	4	3	3	3	3	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
MEAN FAIR WEATHER VALUES																										NUMBER OF CONSTR. MONTHS
$50,000		150,000		260,000		390,000		530,000		670,000		850,000		1,060,000		1,540,000		1,800,000		2,600,000		3,300,000		6,000,000		
7MO.		8 MO		9 MO		10 MO		11 MO		12 MO		13MO		14 MO		15 MO		16 MO		17 MO		18 MO		19 MO		

CWE & CONTRACT DURATION

APPENDIX C


BABCOCK CURVES
MONTHS
PERCENT COMPLETE
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
100 90 80 70 60 50 40 30 20 10 0

APPENDIX D

EXAMPLES OF COMPUTATIONS FOR MONTHLY WIP PROJECTIONS*

GIVEN:

(1) AS OF DATE (always last day of month) - 73JUN30

(2) CONTRACT AWARD DATE (assume last day of month) - 73JAN31

(3) CONTRACT COMPLETION DATE (assume last day of month) - 73OCT31

(4) CONTRACT CURRENT VALUE - $20,000

(5) CONTRACT WORK-IN-PLACE - $10,000

(6) MEAN FAIR WEATHER CURVE TABLE OF PERCENTAGES FOR AN 11 MONTH CONTRACT:

	CUMULATIVE	BY MONTH
1ST MONTH -	2.2	2.2
2ND MONTH -	8.6	6.4
3RD MONTH -	19.4	10.8
4TH MONTH -	34.4	15.0
5TH MONTH -	49.4	15.0
6TH MONTH -	63.8	14.4
7TH MONTH -	75.0	11.2
8TH MONTH -	85.4	10.4
9TH MONTH -	92.3	6.9
10TH MONTH -	97.7	5.4
11TH MONTH -	100.0	2.3

DEFINITIONS:

CONTRACT CURRENT VALUE - The best estimate of the total known and projected cost to accomplish any specific contract plus the sum of all donated and/or liquidated damages recorded on the books against a LEVEL 3 record and reducing program but not allocation

CONTRACT WORK-IN-PLACE - The cost of work put in place for a facility as reported by the ROICC on NAVCOMPT 2311/2312: includes GFM, donated material, liquidated damages, and undistributed contractor material and equipment

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*Provided by FACSO.

ORIGINAL PROJECTION OF MONTHLY WIP (prior to the CONTRACT AWARD DATE and before CONTRACT WORK-IN-PLACE reported)

CONTRACT LENGTH = CONTRACT COMPLETION DATE minus CONTRACT AWARD DATE plus 2 MONTHS
= 73OCT31 - 73JAN31 + 2 MONTHS
= ((73X12)+10) - ((73X12)+1) + 2 MONTHS
= (886) - (877) + 2 MONTHS
= 9 MONTHS + 2 MONTHS
= 11 MONTHS

MONTHLY WIP PROJECTIONS = CONTRACT CURRENT VALUE multiplied by the BY MONTH PERCENTAGES FOR AN 11 MONTH CONTRACT

1ST MONTH	=	$20,000	X .022	=	$	440
2ND MONTH	=	20,000	X .064	=		1,280
3RD MONTH	=	20,000	X .108	=		2,160
4TH MONTH	=	20,000	X .150	=		3,000
5TH MONTH	=	20,000	X .150	=		3,000
6TH MONTH	=	20,000	X .144	=		2,880
7TH MONTH	=	20,000	X .112	=		2,240
8TH MONTH	=	20,000	X .104	=		2,080
9TH MONTH	=	20,000	X .069	=		1,380
10TH MONTH	=	20,000	X .054	=		1,080
11TH MONTH	=	20,000	X .023	=		460

TOTAL PROJECTED WIP WILL = $20,000

REPROJECTING MONTHLY WIP (based on CONTRACT WORK-IN-PLACE)

CONTRACT LENGTH = 11 MONTHS (as computed on prior page)

NUMBER OF MONTHS INTO CONTRACT = AS OF DATE minus CONTRACT AWARD DATE
= 73JUN30 - 73JAN31
= ((73X12)+6) - ((73X12)+1)
= (882) - (877)
= 5 MONTHS

ORIGINAL REMAINING PERCENTAGE = 100 minus CUMULATIVE PERCENTAGE FOR NUMBER OF MONTHS INTO CONTRACT FROM TABLE FOR CONTRACT LENGTH
= 100 - 49.4
= 50.6

REVISED REMAINING PERCENTAGE = 100 - (CONTRACT WORK-IN-PLACE divided by CONTRACT CURRENT VALUE)
= 100 - ($10,000/$20,000)
= 100 - 50
= 50.0

PERCENTAGE RATIO = REVISED REMAINING PERCENTAGE divided by ORIGINAL REMAINING PERCENTAGE
= 50.0 / 50.6
= .99

MONTHLY WIP REPROJECTIONS FOR REMAINING MONTHS OF CONTRACT = CONTRACT CURRENT VALUE multiplied by the BY MONTH PERCENTAGES FROM TABLE FOR CONTRACT LENGTH multiplied by PERCENTAGE RATIO

6TH MONTH	=	$20,000	X	.144	X	.99	=	$ 2,840
7TH MONTH	=	20,000	X	.112	X	.99	=	2,220
8TH MONTH	=	20,000	X	.104	X	.99	=	2,060
9TH MONTH	=	20,000	X	.069	X	.99	=	1,360
10TH MONTH	=	20,000	X	.054	X	.99	=	1,060
11TH MONTH	=	20,000	X	.023	X	.99	=	460

TOTAL PROJECTED WIP = $10,000

GLOSSARY

CAB	Command Advisory Board
Construction Administration	for the purposes of this thesis this term is defined to mean the total workload of administration and inspection.
CMS	Construction Management System
CWE	Current Working Estimate
CQC	Contractor Quality Control
DOD	Department of Defense
EFD	Engineering Field Division
FACSO	Facilities Systems Office
FYDP	Five Year Defense Plan
MCNR	Military Construction, Naval Reserve
MCON	Military Construction, Navy
MIS	Management Information System
NAVCOMPT	Comptroller of the Navy
NAVFAC	Naval Facilities Engineering Command
NMCRB	Navy Military Construction Review Board
NORTHDIV	Northern Division of the Naval Facilities Engineering Command
OICC/ROICC	Officer in Charge of Construction and Resident Officer in Charge of Construction. An OICC has the authority to advertise and award contracts within a specific monetary limit. A ROICC doesn't have advertisement or award authority. He is responsible only for the administration and inspection of contracts assigned by higher authority. See ROICC.
OMB	Office of Management and Budget
O&M,N	Operations and Maintenance, Navy
PCE	Program Cost Estimate

Program Manager - for the purposes of this thesis a Program Manager is defined as a director of one of the ten functional NAVFAC Programs.

ROICC — Resident Officer in Charge of Construction. Most contracting officers have both OICC and ROICC duties, however, for the purposes of this thesis the term ROICC will be used, without regard to OICC authority assigned, to designate that individual responsible for the field administration and inspection of construction contracts.

SIOH — Supervision Inspection and Overhead

WESTDIV — Western Division of the Naval Facilities Engineering Command

WIP — Work-in-place

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